ACTA RADIOLOGICA

FOUNDED IN 1921 BY GÖSTA FORSSELL

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF DENMARK, FINLAND, NORWAY AND SWEDEN

EDITOR ERIK LINDGREN

DIAGNOSIS

SEVENTH SYMPOSIUM

NEURORADIOLOGICUM

NEW YORK

21—25 September 1964

PART II

Skull examinations — Angiography

ACTA RADIOLOGICA

OFFICIAL ORGAN OF THE RADIOLOGICAL SOCIETIES OF
DENMARK FINLAND NORWAY AND SWEDEN

Vol 5 DIAGNOSIS 1966

SEVENTH SYMPOSIUM NEURORADIOLOGICUM NEW YORK

21—25 September 1964

In this special issue we have the privilege of publishing the majority of the papers presented at the Seventh Symposium Neuroradiologicum in New York A few of the papers read at the Symposium were not submitted for publication the titles of these are included in Table of Contents Communications dealing mainly with biologic and therapeutic aspects are published in Volume 5 of the series Therapy Physics Biology

PART I

Table of Contents

NOTICE TO AUTHORS

ACTA RADIOLOGICA publishes selected original papers on medical radiology and nuclear medicine The articles are printed in English, French or German according to the wishes of the author, and are subject to editorial revision the right is reserved to introduce such changes as may be necessary to make the contributions conform to editorial standards Acta Radiologica does not hold itself responsible for opinions expressed by the authors

Papers should not exceed 24 pages, including space for figures and tables Only in exceptional cases will contributions requiring more space be accepted for publication in the journal More extensive articles may be published as Supplements for which special conditions apply

All contributions should ordinarily be addressed, to the *Editorial Secretary Acta Radiologica Box 2052 Stockholm 2 Sweden*. Papers from Denmark Finland and Norway may for convenience be submitted to the Editors of the respective countries for preliminary revision The name and address of the department or hospital at which the work was carried out should be given at the top of the paper, the author should add an address to which correspondence can be directed and retain a copy of the typescript for reference

Contributions should be as clear and concise as possible and typewritten with adequate margins and double spacing (with at least 1 cm between each line) It is important to avoid unessential matter the typescript should therefore be carefully revised before submission Alterations at the proof stage are expensive and with the exception of small corrections will be charged to the author Footnotes should be avoided

Illustrations and tabular material should be unmounted and attached to the typescript in an individual cover hey must be provided with suitable short legends comprehensible without reference to the text and typewritten on a separate page Numbering or any arrowing or lettering should not be drawn on the front of the print submitted but should be marked lightly in pencil on the reverse side together with author s name To ensure good reproduction lines as well as numerals and lettering in diagrams and schematic illustrations should be sharp and well defined and drawn in black Indian ink (never in blue) The thickness of such lines and lettering should allow for adequate reduction The Editor reserves the right to reduce the size of illustrations as considered appropriate If the prints supplied are not of a sufficiently high standard for reproduction purposes the author will be required to submit the original films Colour drawings or colour photographs are not ordinarily acceptable

A short summary not exceeding 75 words must be included The references should be arranged in alphabetical order of the author s name followed by initials full title of the paper, and name of the periodical abbreviated preferably according to the latest edition *World Medical Periodicals* published by WHO and UNESCO, otherwise according to FISHBEIN *Medical Writing* or to the *Quarterly Cumulative Index Medicus* The volume number year within brackets, and number of the first page of the article should follow References to books and monographs should indicate the author title and edition of the book the name of the publisher and the city and year of publication

Examples

BOIJSEN E and DAHN I Selective angiography of bronchial and intercostal arteries. Acta radiol. Diagn 3 (1965), 513

KEITH A Human embryology and morphology edition, p 523 Arnold & Co London 1948

Fifty reprints of each paper are supplied free additional reprints may be purchased at cost provided necessary order is given when the proof is returned

SUBSCRIPTIONS

		in Scandinavia	outside Scandinavia
Acta Radiologica new series for diagnostics (red) for therapeutics (blue) (including physics and biology)	both vols	Sw Kr 90	Sw Kr 100
Acta Radiologica, new series for diagnostics (red)	one vol	Sw Kr 60	Sw Kr 67
Acta Radiologica new series for therapeutics (blue)	one vol	Sw Kr 60	Sw Kr 67

All rates include regular mailing costs

All communications in regard to advertising, subscription, change of address, etc should be sent to Acta Radiologica, Box 2052, Stockholm 2, Sweden

ANGIOGRAPHY

Technique, Subtraction, Anatomy, Vascular lesions Tumour diagnosis Complications

It has been the rule in these special issues of Acta Radiologica that all contributions read at the Symposium and presented to us for publication are accepted As far as possible the same principle has been applied for this Symposium although in some cases the articles in the Editor s opinion deal with aspects of radiology that are already well known The same principles with respect to editorial revision have been applied for these papers as for those in the therapy section In some instances the wording of the titles has been slightly altered The papers are arranged in alphabetical order within adequate subject divisions Owing to the large number of papers and the revision which in some cases was found necessary the work of publication has required a longer time than was originally expected Financial contributions towards the publication of this special issue have been received from the Treasury and Organisers of the Seventh Symposium and Acta Radiological is deeply grateful for this assistance

The Editor

List of Authors

PRESIDENTIAL ADDRESS

First let me thank you, Dr Ruggiero, for the great honor you have bestowed upon me in investing me with this chain of office I shall do my best uphold to the traditions of these Symposia

Ladies and Gentlemen

I take great pleasure in welcoming all of you to the VII Symposium Neuroradiologicum It is my hope that you will enjoy not only the scientific aspects of the Symposium but also generally your visit to this great city of New York

I have endeavored to offer those attending this meeting as interesting and varied a scientific program as was possible I am grateful to the Program Committee for their faithful and valuable assistance in the selection of the papers on the basis of their scientific merit In spite of their careful selection the number of scientific contributions (151) is still large The number of papers presented at this Symposium however is only slightly larger than that of the VI Symposium in Rome at which 147 papers were accepted for presentation At the II Symposium in 1949 there were 24 papers, at the III in Stockholm there were 32 papers and at the IV Symposium in London in 1955 there were already 67 papers

In the earlier Symposia (particularly those of 1949 and 1952) the idea was expressed that these meetings should retain their original quality that is that they should be symposia and not congresses that there should be no set time for presentation of a paper or for the discussion that followed Also the tradition is that a president is selected who is in complete charge of organizing the meeting without being hampered by rules and regulations Unfortunately the first idea is no longer tenable knowledge is accumulating at too rapid a pace and interest in this specialty has grown to a point where it is not practical sufficiently to limit the number of contributors Henceforth probably new criteria must apply papers can only be accepted if they truly represent new knowledge and new research

Growth is inevitable and the increasing number of contributions is a manifestation of increasing interest Evolution of thought is not only inevitable but also necessary if man is to continue to develop and expand his knowledge And so it is that at the first three Symposia there were papers dealing only with radiography of the skull and spine encephalography ventriculography, cerebral angiography and myelography There was one paper, however, at

FROM THE RADIOLOGIC AND UROLOGIC DEPARTMENTS OF THE HOSPITAL FOR SICK CHILDREN TORONTO ONTARIO CANADA

SKULL ABNORMALITIES ASSOCIATED WITH THE ARNOLD CHIARI MALFORMATION

by

E KRUYFF and R JEFFS

Children with a spina bifida often present signs and symptoms of bladder dysfunction — neurogenic bladder It is also known that meningo myeloceles are frequently associated with the so called Arnold Chiari deformity of the hindbrain It seemed of interest to investigate whether a radiologically demonstrable correlation between the spina bifida and possible skull abnor malities existed in these children

Material In a period of 11 months 93 patients with a neurogenic bladder were sent for routine urography, to which was added routine skull radiography Thirteen of them with a history of tumor of or trauma to the spinal cord were excluded from the series (their skull films were normal) Eighty patients had a meningomyelocele their ages ranged from 1 to 16 years (Fig 1) and these are our concern in this study

Spinal defects widening of the spinal canal and neural arch defects were constantly present but to a variable degree and location (Fig 2), 25 % had spinal dysraphism only in the sacral or only in the lumbar area while the majority had involvement of more than one segment of the spine Diastema

the III Symposium devoted to the use of diiodofluorescein in the diagnosis of brain tumors. At the London Symposium a discussion on isotope encephalography was included, and a paper on the use of ultrasound to determine displacement of the midline structures was presented. The latter two methods of diagnosis *received little attention and, I must admit, the preliminary results* of isotope encephalography as reported at that meeting were not too encouraging. Since that time, considerable progress has been made in the field of isotope encephalography and, more recently, the biological uses of ultrasound are receiving increasing attention. While in the beginning ultrasound was used only to determine displacement of the midline structures in the brain, at the present time we are attempting to obtain cross sections of the brain in all planes which will demonstrate the anatomy in each plane. This area offers exciting opportunities for future research. Radiotherapy of tumours of the central nervous system and radiobiology are receiving more attention in this Symposium.

It is my greatest desire and hope that the scientific program of this Symposium will convey to you an accurate idea of what neuroradiology is today.

I am happy to see that there are, distributed widely throughout the program, a number of papers dealing with the research aspects of neuroradiology. I do not see how neuroradiology can endure as a sub-specialty of radiology unless the young men of today are stimulated to seek the truths that lie ahead. It is necessary, therefore, to develop and support independent research in neuroradiology.

Let me take this opportunity to express one last thought. I believe that specialization within radiology has become a necessity. It is generally agreed that it is necessary for the physician or surgeon to become acquainted with all aspects of diagnosis and treatment and, in fact, this should include all diseases. Specialization, however, developed out of the need to provide more knowledge in depth. It is also important for the specialist to know all he can about every aspect surrounding his field. In the case of neurological surgery, in the past the neurosurgeon served not only as clinical neurologist in most instances but also as neuropathologist, neurophysiologist, neuroanatomist and neuroradiologist as well as surgeon. Nowadays the fields have advanced to a degree where such generalization is no longer possible and — granting that we must know all we can about all aspects of our specialties — in order to continue to advance our knowledge it is necessary to concentrate our efforts in a given area to *achieve the only thing that is worthwhile: excellence.*

And with these thoughts I declare open the VIII Symposium Neuroradiologicum.

Juan M. Taveras

FROM THE RADIOLOGIC AND UROLOGIC DEPARTMENTS OF THE HOSPITAL FOR SICK CHILDREN TORONTO ONTARIO, CANADA

SKULL ABNORMALITIES ASSOCIATED WITH THE ARNOLD CHIARI MALFORMATION

by

E KRUYFF and R JEFFS

Children with a spina bifida often present signs and symptoms of bladder dysfunction — neurogenic bladder It is also known that meningo myeloceles are frequently associated with the so called Arnold Chiari deformity of the hindbrain It seemed of interest to investigate whether a radiologically demonstrable correlation between the spina bifida and possible skull abnormalities existed in these children

Material In a period of 11 months 93 patients with a neurogenic bladder were sent for routine urography to which was added routine skull radiography Thirteen of them with a history of tumor of or trauma to the spinal cord were excluded from the series (their skull films were normal) Eighty patients had a meningomyelocele their ages ranged from 1 to 16 years (Fig 1) and these are our concern in this study

Spinal defects widening of the spinal canal and neural arch defects were constantly present but to a variable degree and location (Fig 2) 25 % had spinal dysraphism only in the sacral or only in the lumbar area while the majority had involvement of more than one segment of the spine Diastema

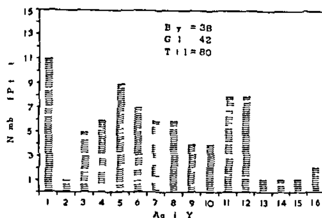


Fig. 1. Distribution of 80 neurogenic bladder patients

tomyelia was seen 5 times. Rib anomalies were seen in 8 %, while hip dislocation was frequently encountered (40 %), in half of this number bilaterally. No attempt was made to classify other congenital defects.

The abnormalities were confined to the skull and particularly to the chondrocranium. These were 1) foramen magnum enlargement, 2) scalloping of the postero medial aspects of the petrous bones, 3) flattening of the floor of the posterior fossa.

In 71 % of the patients a definite and symmetrical enlargement of the foramen magnum was demonstrated. The foramen was seen to be enlarged in all dimensions and often seemed rounder than normal, while in the region of the opisthion a small incisura was sometimes seen. The shapes of the foramen magnum encountered most frequently are shown in Fig. 3, in comparison with the normal foramen magnum (Fig. 4).

The bilateral dimension of the foramen magnum was taken at the largest width of the foramen as seen in the 40° half axial view in the supine position. The length of the foramen was taken by measuring the distance between opisthion and basion in a special lateral projection of the foramen. The results of these measurements and those of normal patients taken for comparison are shown in Table 1. The ages as given are not inclusive.

The second abnormality, a rather peculiar and new one, was seen in the basal view. It consists of a scalloping of the postero medial aspects of the petrous bones (Fig. 5). This was present in 65 %. At post mortem studies of the base of the skull, acquired from a group of infants with meningomyeloceles, which also showed this scalloping of the base in the films, it was revealed that this scalloping was produced by the configuration of a deep sulcus. This groove was running laterally from the non displaced jugular tubercles and medially, posteriorly but also partially inferiorly to the petrous bones and at their

Table 1

Measurements of width and length in millimeters of the foramen magnum in normal and Arnold Chiari skulls (with complete and incomplete triads)

Normal							Arnold Chiari group				
Age in years	Sex	No	Width		Length		No	Width		Length	
			Mean	S D	Mean	S D		Mean	S D	Mean	S D
1—3	♀	16	31	3	39	4 5	6	36	4	50	7
1—3	♂	27	31	2 5	40	5 4	5	38	3 8	46	7
3—7	♀	17	34	2 4	39	4 8	13	43	4 6	51	6 4
3—7	♂	57	34	2 4	43	3 7	5	44	3	51	5 3
7 +		23	35	2 8	44	3 5	11	46	5	52	4 8
7 +	♂	40	35	3 1	44	3 5	18	46	3 4	54	4 8

The measurements for the largest width of the foramen magnum were made from a 40 half axial view in supine position made on the Schonander skull unit the magnification being about 25 The measurements for the length of the foramen magnum basion opisthion were made from special lateral films of the foramen magnum with a focus object distance of 75 cm and object film distance of 15 cm resulting in a magnification of 20

expense (Fig 7 a) at the same time foreshortening the internal meatus (Fig 7 b) This sulcus is not produced by a dilated cistern or by an enlarged sinus but by pressure of the superior and anterior edge of the cerebellum which was found squeezed and lodged into the sulcus

The third abnormality seen in 41 % was a flatness of the floor of the posterior fossa with a shallow posterior fossa and low position of the inion (Fig 8)

These three abnormalities are summarized in Fig 9 The broken line shows that a triad of foramen magnum enlargement flat floor of the posterior fossa and scalloping of the postero medial aspects of the petrous bones was present in only 39 % of our cases Complete normality was observed in 25 % while 36 % showed an incomplete triad

Table 2 combines different skull types with the spinal defects which allows the following observations A normal skull was not found with spinal defects above the lumbar area The triad of skull abnormalities described here was seen in all categories of spinal defects except for the isolated sacral lesion The incomplete triad was seen without special preference while an enlarged skull was a quite constant finding

In none of these patients was evidence obtained of platybasia or basilar impression In none was occipitalization of C1 seen and in only two was a

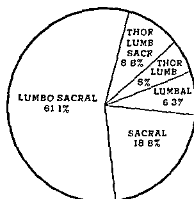


Fig. 2. Distribution of spinal defects in the 80 cases.

fusion of the bodies of C2 and C3 detected. In 20 %, however, a variable degree of displacement of the odontoid process, posteriorly to the line of THIEBAUT, was discovered (Fig. 10). Simultaneously, there was an enlarged foramen magnum. However, no luxation in the atlanto-odontoid joint could be demonstrated. This displacement was present in the neutral position as well as in flexion and extension. It is probably relative and due to the widening of the foramen magnum anteriorly.

Literature

From the beginning we realized that these skull abnormalities stood in close relation to associated intracranial abnormalities. The abnormality most likely to be present was thought to be the Arnold-Chiari deformity of the hindbrain, so often reported in association with meningomyelocele.

In perusing the literature it was realized that many intracranial abnormalities in association with meningomyelocele, other than the Arnold-Chiari deformity, have been described. Reported are deformities and/or defects of the midbrain and aqueduct of Sylvius (6, 13, 16, 37, 39-47, 51-53), diencephalon (6, 20), corpus callosum (16), falx (6, 13), great sinus (6) and vein of Galen (6). The tentorium was found with shallow leaves and low peripheral attachment (6, 13). Hypoplasia or aplasia of the tentorium are recorded, while the incisura was invariably large. The transverse sinus was found displaced inferiorly, running near the rims of the foramen magnum (13). Glial nests are seen in the meninges (11), and heterotopic nodules in the ventricles are reported (6, 11, 16, 23).

The vertebral artery was seen lying in a deep groove of the pons (39, 51), and furthermore microgyri of cerebrum and cerebellum were seen, the latter being often small and asymmetrical (6-8, 9, 13, 16, 50-51, 53). The superior

Table 2

Distribution and frequency of the spinal defects in 80 patients with spina bifida in relation to their skull findings

Group	Skull Particulars	No	Spine: Thoraco lumbar	Thoraco-lumbo-sacral	Lumbo-sacral	Lumbar	Sacral
1	Normal	20	—	—	11	1	8
2	Large foramen magnum Ossa petrosa scalloping Flat posterior fossa Enlarged skull	31	3	4	21	3	—
3	Large foramen magnum Ossa petrosa scalloping Large skull	17	—	2	11	—	4
4	Large foramen magnum Ossa petrosa scalloping	2	—	—	-	—	—
5	Same as sub 2 but without large skull	1	1	—	—	—	—
6	Same as sub 2 but foramen magnum not enlarged	1	—	1	—	—	—
7	Only foramen magnum enlarged	6	—	—	3	1	2
	Incomplete skull investigation	2	—	—	1	—	1
	Total	80	4	7	49	5	15

vermis is often flat and lies in the tentorial *incisura* This flattening is due to the herniation (and pressure) of the overlying *occipital lobe* (53) Hydrocephalus is uniformly reported and *congestion of the* cerebellum could be found which is limited to that part *of the* hindbrain below the level of the foramen magnum

Bony abnormalities however were dealt with less frequently except for the lacunar skull or Luckenschadel also found pathologically by CHIARI (9) and according to KARSHNER & REEVES (33) first reported in 1771 However, this Luckenschadel was not encountered in this material in patients 1 year of age and up RUSSELL reports scalloping of the basiocciput Flattening of the floor of the posterior fossa was noted by HURTEAU in an Arnold Chiari deformity However HURTEAU's case was probably not a proven Arnold Chiari (see Discussion)

Scalloping of the postero medial *aspects* of the petrous bones does not *seem* to have been recorded before

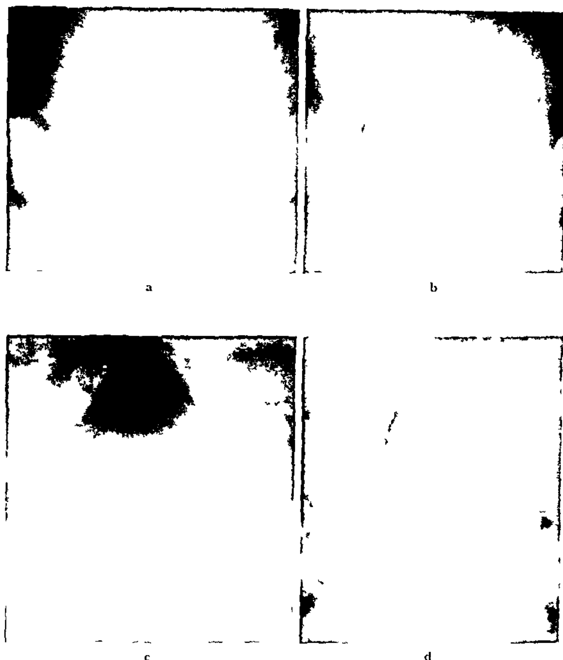


Fig. 3. Examples of shape and size of the foramen magnum in the Arnold Chiari skull. a) A small incisura. c) A more marked incisura at the level of the opisthion. The jugular tubercles are not well seen in (c) and (d), but should not be taken as a sign of posterior fossa tumor. Cf. fig. 4.

Only in pathologic and neurologic publications has enlargement of the foramen magnum occasionally been mentioned and regarded as typical of the Arnold Chiari deformity (6, 9, 13, 41, 50, 58).



Fig 4 Foramen magnum of a normal child for comparison with fig 3 Figs 3 and 4 were taken with a ray direction of 40 from above on the Schonander skull unit Age 8 to 10 years

Discussion

From the beginning we realized that these skull abnormalities stood in close relation to the spinal defects The majority of reports associating spina bifida with other central nervous defects refer to the Arnold Chiari type of hindbrain deformity RUSSELL and DANIEL & STRICH even state that it is clear that whenever a case of meningocele and particularly a meningomyelocele is seen the possibility of an associated Arnold Chiari deformity should be borne in mind This deformity consists of a tail like elongation of the inferior vermis along the roof of the fourth ventricle extending downwards to a variable length over the spinal cord Pons and medulla can be elongated as is the 4th ventricle and can be placed partially into the cervical canal as are the tonsils CHIARI described this abnormality in 1891 and 1895 Since then numerous similar findings have been reported The term Arnold Chiari deformity was coined by SCHWALBE & GREDIG in 1907

In our material of 80 cases of spina bifida it is reasonable to expect the Arnold Chiari deformity in a high percentage The above described skull abnormalities were thought to be sufficiently strong criteria in entertaining this diagnosis The following supporting data are

1 In 5 cases pneumographies and/or posterior fossa explorations have been carried out In each hydrocephalus with a typical elongated 4th ventricle was demonstrated or the typical Arnold Chiari deformity was observed during exploration Two had the complete triad three had an incomplete triad (large foramen magnum and petrous bone scalloping)





Fig 5 Three examples of bilateral scalloping of the postero medial aspects of the petrous bones Interpetrosal distance enlarged meatus acusticus internus cut off medially A waist is seen at the level where normally the petrosal bone has its largest width Compare with fig 6



Fig 6 Aspects of petrosal bones in a normal skull

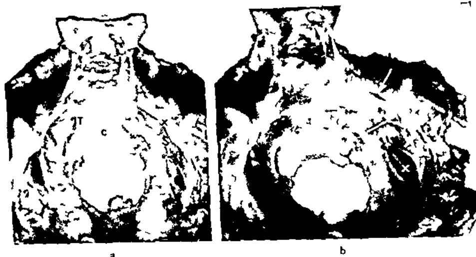


Fig 7 Specimen of posterior fossa of infant with meningomyelocele and a proven Arnold Chiari deformity of the hindbrain a) Seen from above J T — jugular tubercle ↘ — superior petrosal ridge c — basi-occiput s — deep sulcus running posteriorly to the petrosal bone and scalloping it inferiorly b) Specimen slightly rotated to show actual width of sulcus (l—l) →— meatus acusticus internus x — entrance into foramen jugulare

2 Since this study was undertaken we have collected recent post mortem data in 10 infants with meningomyeloceles in which a routine radiologic skull investigation was carried out Each of them demonstrated a large foramen magnum and the same typical scalloping of the petrous bones and in each of them the presence of the Arnold Chiari deformity of the hindbrain could be confirmed

3 Pathologic and neurologic publications, (6 9 13 41 50 58) do refer to the enlarged foramen magnum in the Arnold Chiari deformity although often without concrete figures and seldom referring to the basion opisthion distance

A large foramen magnum is not typical only for the Chiari type II or Arnold Chiari deformity CHIARI himself described in his type III deformity of the hindbrain the presence of a large foramen magnum This Chiari type III deformity is also known under the synonym Klippel Feil and iniencephaly (9) In this type however severe cervical defects are encountered often with occipito cervical meningo-encephalocele and is easily recognized as such

Flatness or straight floor of the posterior fossa which at the same time is shallow was seen in 41 % Probably it is not pathognomonic for the Arnold Chiari deformity although HURTEAU reported this flattening as typical



Fig. 8. Lateral view of the skull demonstrating the flat floor of a rather shallow posterior fossa.

His patient, a 25 year old woman, however, did not have hydrocephalus and at posterior fossa exploration only severe tonsil herniation and adhesions were observed; findings of the typical tail which go with the Arnold Chiari deformity were not reported.

It is rather striking and significant that in none of our patients was there any evidence of platybasia, basilar impression or occipitalization of C1. Only twice was a fusion of the bodies of C2 and C3 noted. We do not think that these abnormalities are typical of the Arnold Chiari deformity; however, a rare exception will exist. In none of the classic pathologic publications (2, 6, 8, 9, 13, 24, 39, 51, 52, 53, 56) was this combination mentioned. Many published cases of Arnold Chiari deformity (3, 4, 10, 12, 25, 34, 38, 42, 43, 44, 46, 56, 59, 60) with congenital occipital bone abnormalities, platybasia, basilar impression and occipitalization of C1, are in fact not (proven) Arnold Chiari deformities with the possible exceptions of Cases 5 and 6 from List. The fact that in these cases the tonsils were found herniated is not evidence enough and not proof of the Chiari type II defect, but makes it more likely to classify them as possible Chiari type I deformities.

Also many publications (1, 5, 15, 22, 26, 35, 45, 57, 59) claiming Arnold Chiari deformities without the presence of occipital bone and spine abnormalities, are in fact not proven Arnold Chiari, but possible Chiari type I deformities. Only Peach's recent publication is probably the first proven Arnold Chiari deformity without spinal dysraphism. In fact, his paper is a welcome contribu-

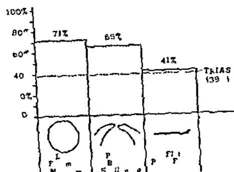


Fig 9 Skull abnormalities most frequently encountered in the material Schematic drawing

tion which happily refuted the myth about the Arnold Chiari deformity as caused by traction of a tethered cord and diastematomyelia

We know from pathologic studies among others RUSSELL (51 53), that a wide range exists in the severity and degree of hindbrain deformities in meningomyelocele patients Grades of cerebellar hypoplasia are encountered Probably the inconsistency of our radiologic findings depends on these varieties already documented by CHIARI in 1891 and 1895 The complete as well as the incomplete Arnold Chiari skulls were larger than normal with often evidence of a certain degree of arrested hydrocephalus Detailed analysis of size and shape of these skulls was not helpful because of the variety of treatment (shunting procedures repair of meningomyelocele conservative treatment) and age at which treatment was initiated The upper cervical spine was not infrequently wider than normal The patient s face was often rather without expression even in many with normal school progress However voluntary facial muscle movements were normal

The number of normal skulls was rather large in this series We know that spina bifida does occur without the Arnold Chiari deformity but the percentage here is rather high Probably this may be properly explained by the fact that our group of patients is a self selected group out of an original material of over 1 500 cases of spina bifida of which the fittest survived

With the progress in surgical procedures and chemotherapy, more and more of these patients are expected to survive and reach adolescence Skull films made in these patients can inform us about possible problems and complications to be expected We lost 4 patients rather suddenly, unfortunately without post mortem studies we are still in the dark as to whether their sus

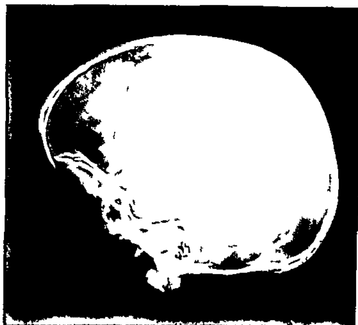


Fig. 8. Lateral view of the skull demonstrating the flat floor of a rather shallow posterior fossa.

His patient, a 25 year old woman, however, did not have hydrocephalus and at posterior fossa exploration only severe tonsil herniation and adhesions were observed; findings of the typical tail which go with the Arnold Chiari deformity were not reported.

It is rather striking and significant that in none of our patients was there any evidence of platybasia, basilar impression or occipitalization of C1. Only twice was a fusion of the bodies of C2 and C3 noted. We do not think that these abnormalities are typical of the Arnold Chiari deformity, however a rare exception will exist. In none of the classic pathologic publications (2, 6-8, 9, 13, 24, 39, 51, 52, 53, 56) was this combination mentioned. Many published cases of Arnold Chiari deformity (3, 4, 10, 12-25, 34, 38, 42, 43, 44-46, 56, 59, 60) with congenital occipital bone abnormalities platybasia, basilar impression and occipitalization of C1, are in fact not (proven) Arnold Chiari deformities, with the possible exceptions of Cases 5 and 6 from LIST. The fact that in these cases the tonsils were found herniated is not evidence enough and not proof of the Chiari type II defect, but makes it more likely to classify them as possible Chiari type I deformities.

Also many publications (1-5, 15, 22, 26, 35-45, 57, 59) claiming Arnold Chiari deformities without the presence of occipital bone and spine abnormalities, are in fact not proven Arnold Chiari, but possible Chiari type I deformities. Only PEACH's recent publication is probably the first proven Arnold Chiari deformity without spinal dysraphism. In fact his paper is a welcome contribu

ing of the postero medial aspects of the petrous bones which was produced by a sulcus in this area In this sulcus was lodged the supero anterior edge of the cerebellum This scalloping was always seen in the presence of a large foramen magnum Post mortem findings of the Arnold Chiari type of hindbrain deformity in a group of infants with meningomyelocele and with the same findings as described above support the idea that the presence of the Arnold Chiari or Chiari type II deformity of the hindbrain can be suspected if such skull abnormalities are present

SUMMARY

The radiologic features in patients with spina bifida are described These are enlargement of the foramen magnum and scalloping of the postero-medial inferior aspects of the ossa petrosa Flatness of the floor of the posterior fossa was also seen though less frequently These findings some of them new are presented as evidence for the presence of Arnold Chiari deformity of the hindbrain Because of this it was suggested that skulls with this triad of abnormalities be named the Arnold Chiari or Chiari type II skulls

ZUSAMMENFASSUNG

Die radiologischen Zeichen in Patienten mit spina bifida werden beschrieben Diese sind Vergrösserung des Foramen occipitale magnum und Unregelmassigkeiten im post medial inferioren Aussehen der Ossa petrosa Plattheit des Bodens der hinteren Fossa war auch zu sehen obwohl weniger haufig Diese Befunde von denen manche neu sind werden als Beweis fur eine Arnold Chiari Missbildung des Rautenhirns gedeutet Dieses berucksichtigend schlagen die Verfasser vor dass Schadel mit diesen Abnormalitaten Arnold Chiari oder Chiari Typ II Schadel genannt werden

RÉSUMÉ

Description des signes radiologiques chez les malades atteints de spina bifida Il y a agrandissement du trou occipital et irrégularités des parties postéro-internes et inférieures des rochers On a constaté aussi mais moins souvent l aplatissement du plancher de la fosse postérieure Ces signes dont certains sont nouveaux sont présentés comme la preuve qu il y a une malformation d Arnold Chiari de la partie postérieure de l encéphale C est pourquoi les auteurs proposent d appeler crânes d Arnold Chiari ou cranes de Chiari type II les cranes qui presentent cette triade d anomalies

REFERENCES

1 ARING C D Cerebellar syndrome in an adult with malformation of the cerebellum and brain stem (Arnold Chiari deformity) with a note on the occurrence of Torpedoes in the cerebellum J Neurol Neurosurg Psychiat 1 (1938) 100

2 ARNOLD J Myelocyste Transposition von Gewebskeimen und Sympodie Beitr path anat 16 (1894) 1



Fig. 10. Odontoid process seen protruding posteriorly to the line of Thiebaut.

pected hydrocephalus and hindbrain deformity had contributed to their death.

The Arnold Chiari deformity might be suspected from skull films also in those cases in which no spine deformities are present. Furthermore, in the differential diagnosis of hydrocephalus, it is good to note that the skull abnormalities described and introduced here are not seen in Dandy Walker, hydrocephalus due to cisternal block or posterior fossa tumors.

Conclusion

In a routine skull investigation of neurogenic bladder patients, on the basis of a spina bifida, it was found that certain deformities of the chondrocranium appeared in a high frequency. These skull abnormalities are 1) enlargement of the foramen magnum, 2) scalloping of the postero-medial inferior aspects of the petrous bones and 3) flat floor of the posterior fossa.

Evidence from the literature was collected which favours the view that an enlarged foramen magnum is present in the Arnold Chiari deformity of the hindbrain. Although such enlargement is also seen in the Chiari type III deformity, the latter can easily be differentitated from the Chiari II deformity.

A skull abnormality which appeared to be totally new was a peculiar scallop

24 GREENFIELD J G BLACKWOOD W McMENEMEY W H MEYER A and NORMAN R M Neuropathology Edward Arnold (Publ) Ltd London
25 GROS C ROILGEN A VLAHOVITCH B et ARTIGALA MIJOVIC Problemes diagnostiques complexes posés par la maladie d Arnold Chiari Montpellier med 3 (1960) 231
26 HURTEAU E F Arnold Chiari malformation J Neurosurg 7 (1950) 282
27 INGRAHAM F D and SWAN H Spina bifida and cranium bifidum encephalocele A survey of 546 cases New Engl J Med 228 (1943) 559
28 — and HAMLIN H Spina bifida and cranium bifidum Surgical treatment New Engl Med J 228 (1943) 631
29 — and MATSON D D Neurosurgery of infancy and childhood Thomas Springfield Ill 1954
30 — and SCOTT H W Spina bifida and cranium bifidum The Arnold Chiari malformation New Engl J Med 229 (1943) 108
31 JACOBS E B LANDING B H and THOMAS W Vermicomyelia Amer J Path 39 (1961) 345
32 KAPSENBERG J G and VAN LOOKERN CAMPAGNE J A Spina bifida combined with diastematomyely anomaly of Chiari and hydrocephaly case Acta anat 7 (1949) 366
33 KARSHNER R G and REEVES D L Lacunar skull (Luckenschadel) of the newborn Amer J Roentgenol 57 (1947) 321
34 KISSEL P ARNOLD G TRIDON P et SCHMITT J Malformation rare de la charniere occipito-vertebrale associée à une anomalie d Arnold Chiari et a un raccourcissement congénital des deux humérus Rev neurol (1960) 102
35 KRAYENBUHL H Chronic internal hydrocephalus due to abnormality of cerebellum related to Arnold Chiari deformity Schweiz med Wschr 71 (1941) 414
36 LAURENCE K M The natural history of Spina bifida cystica Proc roy Soc Med 53 (1960) 1055
37 LAVY S EYAL Z and SCHWARTZ A Neurological and surgical experiences in Arnold Chiari malformation Acta neurochir (Wien) (1960) 532
38 LEWIN J R WYCIS H T and YOUNG B R Roentgen diagnosis of herniation of brain into spinal canal (Arnold Chiari deformity) by pantopaque myelography Radiology 54 (1950) 591
39 LICHTENSTEIN B W Atresia and stenosis of the aqu duct of Sylvius J Neuropath exp Neurol 18 (1959) 3
40 LICHTENSTEIN W B Spinal Dysraphism Spina bifida and myelodysplasia Arch Neurol Psychiat 44 (1940) 792
41 LIST C F Neurologic syndromes accompanying developmental anomalies of occipital bone atlas and axis Arch Neruol Psychiat 45 (1941) 578
42 LOUGHEED L E BAKER G S and MULDER D W Arnold Chiars malformation in adults Report of a case Proc Mayo Clin 32 (1957) 632
43 MALIS L I COHEN I and GROSS S W Arnold Chiari malformation Arch Surg 63 1951 783
44 MARKS J H and LIVINGSTONE K E The cervical subarachnoid space with particular r ference to syringomyelia and the Arnold Chiari deformity Radiology 52 (1949) 63
45 McCONNEL A A and PARKER H L Deformity of hind brain associated with internal hydrocephalus its relation to Arnold-Chiari malformation Brain 61 (1938) 415

3 BARTSTRA H K Malformatie van Arnold Chiari en Platybasia Folia psychiat neerl 57 (1954) 104
4 BLOOM W H Arnold Chiari malformation report of a case Arch Neurol Psychiat 66 (1951) 228
5 BUCY P and LICHTENSTEIN B W Arnold Chiari deformity in adult without obvious cause J Neurosurg 11 (1945) 245
6 CAMERON A H The Arnold Chiari and other neuro anatomical malformations associated with spina bifida J Path Bact 73 (1957) 195
7 — Malformation of the neuro spinal axis, urogenital tract and foregut in spina bifida attributable to disturbances of the blastopore J Path Bact 73 (1957) 213
8 CHIARI H Über Veränderungen des Kleinhirns des Pons und der medulla oblongata in Folge von congenitaler Hydrocephalie des Grosshirns Denkschr Akademie d Wissensch 63 (1895) 71
9 — Über Veränderungen des Kleinhirns in Folge von Hydrocephalie des Grosshirns Dtsch med Wschr 42 (1891), 1172
10 COGAN D G and LAWRENCE J B Platybasia and the Arnold Chiari malformation A M A Arch Ophthal 52 (1954) 13
11 COOPER I S and KERNOHAN J W Heterotopic glial nests in subarachnoid space Histopathologic characteristics mode of origin and relation to meningeal gliomas J Neuropath exp Neurol 10 (1951) 16
12 COSSA P DUPLAY M MARTIN J AUBERT D et HUMMI M Malformation D Arnold Chiari Impression basilaire invagination basilaire platybasie convexobasie aplasie de la lame basilaire A propos de deux observations Rev neurol 85 (1951) 392
13 DANIEL P M and STRICH J Some observations on the congenital deformity of the central nervous system known as the Arnold Chiari malformation J Neuropath exp Neurol 17 (1958) 255
14 DORAN P A and GUTHKELCH A W Studies in spina bifida Part IV The frequency and extent of paralysis J Neurol Neurosurg Psychiat 26 (1963) 545
15 EPSTEIN B S Pantopaque myelography in the diagnosis of the Arnold Chiari malformation without concomitant skeletal or central nervous system defects Amer J Roentgenol 59 (1948) 359
16 *FLEGIN I Arnold Chiari malformation with associated analogous malformation of the* midbrain Neurology 6 (1956) 22
17 GARDNER W J Anatomic features common to the Arnold Chiari and the Dandy Walker malformations suggest a common origin Cleveland Clin Found 26 (1959) 206
18 — Anatomic anomalies common to myelomeningocele of infancy and syringomyelia of adulthood suggest a common origin *Cleveland Clin Quart 26 (1959) 118*
19 — Rupture of the neural tube Arch Neurol 4 (1961) 1
20 — Myelomeningocele the result of rupture of the embryonic neural tube Cleveland Clin Quart 27 (1960) 88
21 — and COLLIS J S Klippel Feil syndrome (syringomyelia diastematomyelia and *myelomeningocele) — one disease? Arch Surg 83 (1961) 638*
22 — and GOODALL R J Surgical treatment of the Arnold Chiari malformation in adults J Neurosurg 7 (1950) 199
23 — ABDULLAH A F and McCORMACK L J Varying expressions of embryonal atresia of fourth ventricle in adults Arnold Chiari malformation Dandy Walker syndrome arachnoid cyst of cerebellum and syringomyelia J Neurosurg 14 (1957) 591

24 GREENFIELD J G BLACKWOOD W McMENEMEY W H MEYER A and NORMAN R M Neuropathology Edward Arnold (Publ) Ltd London

25 GROS C ROILGEN A VLAHOVITCH B et ARTIGALA Mijovic Problèmes diagnostiques complexes posés par la maladie d Arnold Chiari Montpellier med 3 (1960) 231

26 HURTEAU E F Arnold Chiari malformation J Neurosurg 7 (1950) 282

27 INGRAHAM F D and SWAN H Spina bifida and cranium bifidum encephalocele A survey of 546 cases New Engl J Med 228 (1943) 559

28 — and HAMLIN H Spina bifida and cranium bifidum Surgical treatment New Engl Med J 228 (1943) 631

29 — and MATSON D D Neurosurgery of infancy and childhood Thomas Springfield Ill 1954

30 — and SCOTT H W Spina bifida and cranium bifidum The Arnold Chiari malformation New Engl J Med 229 (1943) 108

31 JACOBS E B LANDING B H and THOMAS W Vermicomyelia Amer J Path 39 (1961) 345

32 KAPSENBERG J G and VAN LOOKERN CAMPAGNE J A Spina bifida combined with diastematomyely anomaly of Chiari and hydrocephaly case Acta anat 7 (1949) 366

33 KARSHNER R G and REEVES D L Lacunar skull (Luckenschadel) of the newborn Amer J Roentgenol 57 (1947) 321

34 KISSEL P ARNOULD G TRIDON P et SCHMITT J Malformation rare de la charnière occipito-vertébrale associée a une anomalie d Arnold Chiari et à un raccourcissement congénital des deux humérus Rev neurol (1960) 102

35 KRAYENBUHL H Chronic internal hydrocephalus due to abnormality of cerebellum related to Arnold Chiari deformity Schweiz med Wschr 71 (1941) 414

36 LAURENCE K M The natural history of Spina bifida cystica Proc roy Soc Med 53 (1960) 1055

37 LAVY S EYAL Z and SCHWARTZ A Neurological and surgical experiences in Arnold Chiari malformation Acta neurochir (Wien) (1960) 532

38 LEWIN J R WYCIS H T and YOUNG B R Roentgen diagnosis of herniation of brain into spinal canal (Arnold Chiari deformity) by pantopaque myelography Radiology 54 (1950) 591

39 LICHTENSTEIN B W Atresia and stenosis of the aqueduct of Sylvius J Neuropath exp Neurol 18 (1959) 3

40 LICHTENSTEIN W B Spinal Dysraphism Spina bifida and myelodysplasia Arch Neurol Psychiat 44 (1940) 792

41 LIST C F Neurologic syndromes accompanying developmental anomalies of occipital bone atlas and axis Arch Neruol Psychiat 45 (1941) 578

42 LOUGHEED L E BAKER G S and MULDER D W Arnold Chiari malformation in adults Report of a case Proc Mayo Clin 32 (1957) 632

43 MALIS L I COHEN I and GROSS S W Arnold Chiari malformation Arch Surg 63 (1951) 783

44 MARKS J H and LIVINGSTONE K E The cervical subarachnoid space with particular reference to syringomyelia and the Arnold Chiari deformity Radiology 52 (1949) 63

45 McCONNELL A A and PARKER H L Deformity of hind brain associated with internal hydrocephalus its relation to Arnold Chiari malformation Brain 61 (1938) 415

46 MULLAN S and RAIMONDI A J Respiratory hazards of the surgical treatment of the Arnold Chiari malformation J Neurosurg 19 (1962), 675
47 OGRYZLO M A The Arnold Chiari malformation Arch Neurol Psychiat 48 (1942), 30
48 PEACH B Arnold Chiari Malformation with normal spine A M A Arch Neurol 10 (1964) 497
49 PENFIELD W and COBURN D F Arnold Chiari malformation and its operative treatment Arch Neurol Psychiat 40 (1938) 328
50 RICARD A et GIRARD P F Difformité d Arnold Chiari Rev neurol 81 (1949) 332
51 RUSSELL D S and DONALD C The mechanism of internal hydrocephalus in spina bifida Brain 58 (1935), 203
52 — Hydrocephalus in neurology and psychiatry in childhood Res Publ Ass nerv ment Dis 34 (1954) 160
53 — *Observations on the pathology of hydrocephalus Spec Rep Ser med Res Coun* No 265 (1949)
54 SANDBANK U Le syndrome d Arnold Chiari Rev neurol 93 (1955) 529
55 SCHMID W *Ein Fall von Hypoplasie und einseitiger Assimilation* des Atlas mit Platybasie basilarer Impression und Arnold Chiarischer Anomalie Schweiz Arch Neurol 88 (1961) 147
56 SCHWALBE F und GREDIG M Über Entwicklungsstorungen des Kleinhirns Hirnstammis und Halsmarks bei spina bifida Beitr path Anat 40 (1907) 132
57 SWANSON H S and FINCHER E F Arnold Chiari deformity without bony anomalies J Neurosurg 6 (1949) 314
58 THIEBAUT F Le diagnostic radiologique des malformations cerebellobulbaires décrites par Chiari Roentgen Europ 6—7 (1962) 209
59 VERBIEST H The Arnold Chiari malformation in adults without concomitant anomalies of the skull or the vertebral column Folia psychiat neerl 56 (1953) 544
60 — The Arnold Chiari malformation J Neurol Neurosurg Psychiat 16 (1953) 227

FROM THE DEPARTMENT OF RADIOLOGY AND NEUROLOGY, INDIANA UNIVERSITY SCHOOL OF MEDICINE INDIANAPOLIS INDIANA U S A

ROENTGENOLOGY OF HOLOPROSENCEPHALY

(Arhinencephaly)

by

G J KURLANDER W DEMYER J A CAMPBELL and H TAYBI

The classification of malformations recognized under the heading arhinencephaly has recently been revised A generic term holoprosencephaly has been suggested (ref 5) This communication will outline the developmental anatomy of holoprosencephaly and the accompanying craniofacial malformations The intimate relationship between prosencephalic and median facial development provides a reliable means of predicting the more severe degrees of brain malformation on the basis of the clinical and roentgen features of the facial configuration (ref 7)

Developmental anatomy Fig 1 depicts the three primary and five secondary brain vesicles that ultimately develop into the adult brain In the severe form of holoprosencephaly (*alobar*) the prosencephalon remains as a holosphere with a single ventricular cavity This holosphere is covered by gyri with cerebral cortex and corresponds to the posterior frontal parietal occipital and temporal lobes of the normal brain The anterior portions of the frontal lobes the frontal poles do not develop A fluid containing dorsal sac found posterior to the prosencephalon probably represents the evaginated roof of the prosen

Table

Face	Brain	Cranium	Orbit
Cyclopia	Alobar holoprosencephaly: small monoventricular *undivided* cerebrum; roof of cerebral ventricle a thin membrane which may be ballooned dorsally forming a dorsal sac; absent olfactory bulbs and tracts; corpus callosum absent or rudimentary; unseparated thalami. Hippocampi remain in dorsal position	Microcephaly	Single
Ethmocephaly		Microcephaly	Two but extreme hypotelorism
Cebocephaly		Microcephaly	Hypotelorism
With median cleft lip		Microcephaly and sometimes trigonocephaly	Hypotelorism
Too few facial descriptions to establish a pattern	Semilobar holoprosencephaly: small brain; cerebral lobes present but rudimentary; interhemispheric fissure lacking; cerebral neocortex in continuity across midline; olfactory bulbs and tracts usually but not always absent; corpus callosum rudimentary	Microcephaly	Hypotelorism or hypertelorism (?)
Philtrum premaxilla anlage (brain type A lobar holoprosencephaly)	*Lobar holoprosencephaly* Type A — With midline continuity of frontal neocortex Type B — With complete separation of neocortex across the midline	Microcephaly and sometimes trigonocephaly	Hypotelorism
May or may not have obvious malformations (brain type A or B lobar holoprosencephaly)	Well formed lobes which may be of normal size; interhemispheric fissure present but may be interrupted anteriorly if neocortex is in continuity across midline; olfactory bulbs and tracts may or may not be present; corpus callosum may be absent, hypoplastic or normal; a dorsal sac may be present communicating with the third ventricle and extending upwards between the hemispheres	May have trigonocephaly	Hypotelorism, normal or hypertelorism (?)

Table *(cont.)*

Nose	Proboscis	Upper lip	Primary palate	Maxillae and secondary palate**	Midline facial bones
Absent	Present above orbit	Uncleft	Absent	Underdeveloped and fused or in direct contact	Absent
Absent	Present	Uncleft	Absent	Underdeveloped and fused or in direct contact	Absent
Flat and rudimentary with a single median nostril	Absent	Uncleft	Absent	Fused or in direct contact	Absent
Flat	Absent	Median cleft	Often absent	Usually with cleft secondary palate	Absent
	Absent				
Nasal bridge present but hypoplastic	Absent	Bilateral lateral cleft	Present but hypoplastic	Cleft secondary palate	Present but rudimentary
Nasal bridge present and well formed	Absent	May have unilateral or bilateral cleft	Hypoplastic or normal	Secondary palate may or may not be cleft	Present

Primary palate is anterior to incisive foramen; it is a lip structure developmentally (ref. 11).
Secondary palate is posterior to incisive foramen; it develops bilaterally from the palatine processes of the maxillary bones after the [illegible]

Table

Face	Brain	*Cranium*	*Orbit*
Cyclopia	Alobar holoprosencephaly small *monoventricular undivided cerebrum* roof of cerebral ventricle a thin membrane which may be ballooned dorsally forming a dorsal sac absent olfactory bulbs and tracts *corpus callosum absent or rudimentary* unseparated thalami Hippocampi remain in dorsal position	Microcephaly	Single
Ethmocephaly		Microcephaly	Two but extreme hypotelorism
Cebocephaly		Microcephaly	Hypotelorism
With median cleft lip		Microcephaly and sometimes trigonocephaly	Hypotelorism
Too few facial descriptions to establish a pattern	*Semilobar holoprosencephaly* small brain cerebral lobes present but rudimentary interhemispheric fissure lacking cerebral neocortex in continuity across midline olfactory *bulbs and tracts usually but not* always absent corpus callosum rudimentary	Microcephaly	Hypotelorism or hypertelorism (?)
Philtrum premaxilla anlage (brain type A lobar holoprosencephaly)	*Lobar holoprosencephaly* Type A – With midline continuity of frontal neocortex Type B – With complete separation of neocortex across the midline	Microcephaly and sometimes trigonocephaly	Hypotelorism
May or may not have obvious malformations (brain type A or B lobar holoprosencephaly)	Well formed lobes which may be of normal size interhemispheric fissure present but may be interrupted anteriorly if neocortex is in continuity across midline olfactory bulbs and tracts may or may not be present corpus callosum may be absent hypoplastic or normal a dorsal sac may be present communicating with the third ventricle and extending upwards between the hemispheres	May have trigonocephaly	Hypotelorism normal or hypertelorism (?)



Fig ? C e l Microcephaly hypotelo sm and median cleft l p fac al type Keel shaped forehead and supra if ry depress on of tr gonocephaly (Reproduced by permission from Confinia Neurolog ca)

fissure are well formed but one or more anomalies reflect the tendency for incomplete prosencephalic development These anomalies include among others midline continuity of the frontal neocortex agenesis of the olfactory bulbs and tracts broad communication of the lateral ventricles and agenesis or hypoplasia of the corpus callosum with or without a dorsal sac Since de fects in development of the corpus callosum may result from a variety of mechanisms not all cases of this anomaly are related to holoprosencephaly

Brain and craniofacial relationships Embryologically the spinal cord and brain stem up to the caudal limit of the *prosencephalon* are induced by notochordal mesoderm The prosencephalon is induced by *the prechordal* mesoderm be tween it and the foregut (ref 9) This prechordal mesoderm not only induces prosencephalic development but also *is the anlage of* the median facial struc tures which are the ethmoid including the crista galli nasal and vomer bones as well as the nasal septum Also included *in the* median facial structures are the components of the upper oral arch of naso *medial* (medial) origin which are called the intermaxillary segment The intermaxillary segment is comprised of three parts 1) a labial component which *forms the* philtrum of the upper lip 2) an upper jaw component, the premaxilla which normally carries four incisor teeth and 3) a palatal component which forms the triangular primary

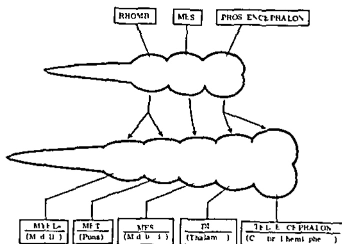


Fig. 1. The three primary and five secondary brain vesicles that ultimately develop into the normal brain.

cephalic monoventricle. In addition, the cerebrum arrested at this stage of development contains unseparated thalami. The olfactory bulbs and tracts are absent because they fail to evaginate, and the hippocampi remain in dorsal position. Absence of the olfactory bulbs and tracts led KUNDRAT to call the malformation 'arhinencephaly'. Several other tectogenic transformations fail to occur in this primitive brain (ref. 5).

Since the arrest in cerebral development can occur at successively later stages of embryogenesis a spectrum of related but less severe malformations is encountered. KUNDRAT and later authors have considered this spectrum to extend from cyclopia to agenesis of the corpus callosum: 1) cyclopia, 2) ethmocephaly, 3) cebocephaly, 4) with median cleft lip, 5) with bilateral lateral cleft lip, 6) with trigonocephaly, and 7) with agenesis of the corpus callosum (ref. 2). Although these groups have been classed under the heading 'arhinencephaly', the term is unsatisfactory because undue stress is placed on only one of the many cerebral defects, and in fact some brains belonging to this teratologic series have olfactory bulbs and tracts (ref. 5). Holoprosencephaly was suggested because it connotes an arrest in cleavage of the prosencephalon into cerebral hemispheres, and emphasizes the holistic, primitive nature of the undivided prosencephalon (ref. 5).

Classification. In alobar holoprosencephaly, the most severe form of this brain malformation, no interhemispheric fissure and no lobes are present. It is found in cyclopia, ethmocephaly, cebocephaly, and median cleft lip (see Table). In semilobar holoprosencephaly lobes are recognized but no interhemispheric fissure is present. In lobar holoprosencephaly, lobes and an interhemispheric

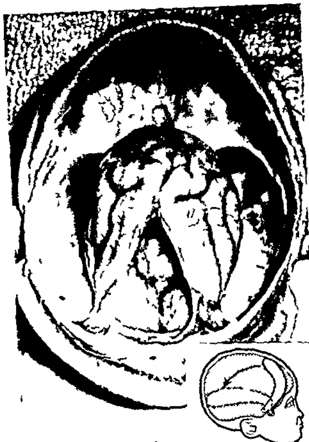


Fig 4 Case I Alobar holoprosencephalon as seen at post mortem with superior part of calvaria removed *Thin membrane forming the dorsal sac has also been removed* Large fluid filled spaces were present in front of and behind the cerebral substance Diagram at lower right illustrates the variable position of the holotelencephalon within the skull Fluid posterior to the holotelencephalon is contained in the dorsal sac which is completely separate from the space in front (Reproduced by permission from Archives of Neurology)

not developed sufficiently to separate the occipital lobes The literature contains incomplete descriptions of the facial patterns in this group of cerebral malformations Thus the reliable predictability of the brain malformation by the craniofacial configuration in alobar holoprosencephaly has not been firmly established with semilobar holoprosencephaly The facial features noted in the few completely reported cases included broad flat nose, and hypotelorism with or without trigonocephaly

The brains with lobar holoprosencephaly have well formed lobes and may be of normal size An interhemispheric fissure is present but may be interrupted anteriorly if the frontal neocortex is in continuity across the midline Many patients in this group will not have obvious facial malformations Those who do may have hypotelorism with or without trigonocephaly, cleft lip or cleft palate

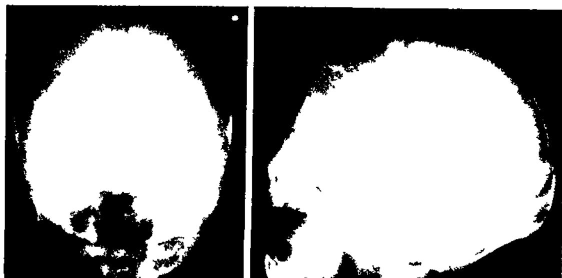


Fig. 3. Case 1. Frontal and lateral skull roentgenograms indicate microcephaly and orbital hypotelorism. Longest diameters of the orbits are convergent superomedially. Nasal and median facial bones are absent. Metopic suture is open (postmortem confirmation).

palate. The intermaxillary segment is continuous with the rostral portion of the nasal septum which is also of medial origin. The major portion of the definitive palate is formed by the palatine shelves which arise laterally from the maxillary swellings. These shelves fuse in the midline and form the secondary palate. Anteriorly they fuse with the triangular primary palate. The midline boundary between the primary and secondary palates is the incisive foramen (ref. 8). Interference with prechordal mesoderm, therefore, can cause defects in the median facial bones and intermaxillary segment as well as incomplete prosencephalic development. Disturbances in the inductive activity of the prechordal mesoderm might be caused by a number of factors including physical, toxic, metabolic or genetic disturbances all leading to similar craniofacial and brain malformations (ref. 5).

Craniofacial malformations are invariably present in alobar holoprosencephaly. Orbital hypotelorism is constant. Other anomalies which may appear in varying degrees and combinations are absence of the nasal septum, median and bilateral lateral clefts of the lip and primary palate, median cleft of the secondary palate, microphthalmia, anophthalmia, micrognathia, small frontal bones sometimes with trigonocephaly, and arhinia with or without a proboscis. Patients with cyclopia, ethmocephaly, cebocephaly, and median cleft lip are included in this category of brain and facial malformations.

In semilobar holoprosencephaly the brain is small but cerebral lobes can be identified. The interhemispheric fissure may be suggested posteriorly but is

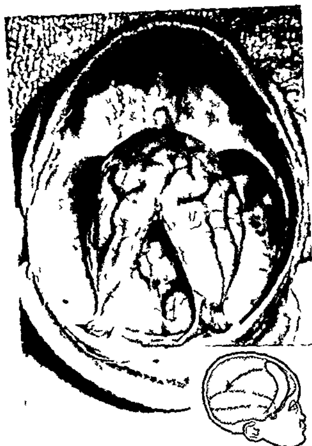


Fig 4 Case 1 Alobar holoprosencephalon as seen at postmortem with superior part of calvaria removed Thin membrane forming the dorsal sac has also been removed Large fluid filled spaces were present in front of and behind the cerebral substance Diagram at lower right illustrates the variable position of the holotelencephalon within the skull Fluid posterior to the holotelencephalon is contained in the dorsal sac which is completely separate from the space in front (Reproduced by permission from Archives of Neurology)

not developed sufficiently to separate the occipital lobes The literature contains incomplete descriptions of the facial patterns in this group of cerebral malformations Thus the reliable predictability of the brain malformation by the craniofacial configuration in alobar holoprosencephaly has not been firmly established with semilobar holoprosencephaly The facial features noted in the few completely reported cases included broad flat nose and hypotelorism with or without trigonocephaly

The brains with lobar holoprosencephaly have well formed lobes and may be of normal size An interhemispheric fissure is present but may be interrupted anteriorly if the frontal neocortex is in continuity across the midline Many patients in this group will not have obvious facial malformations Those who do may have hypotelorism with or without trigonocephaly cleft lip or cleft palate



Fig. 3. Case 2. Frontal and lateral skull roentgenograms indicate orbital hypotelorism. Nasal and median facial bones are absent. Palatine processes of the maxillary bones are fused in the midline (arrow). Ethmoidal labyrinths are hypoplastic. Longest diameters of the orbits in the frontal view are vertically oriented and contour of superior margins is semicircular ("half moon").

Case material. Seventeen patients with holoprosencephaly have been studied at this institution in the recent past, and almost all have had complete post mortem examinations. Of this group, 10 had satisfactory roentgen evaluation of the skull or brain. Brief summaries of 6 of these 10 cases are presented below.

The behavior pattern has been quite similar in patients with the most severe form of this brain malformation, alobar holoprosencephaly (ref. 5). These patients were able to swallow, cry, and move their extremities and eyes but none showed any developmental progress. They all had numerous convulsions and poikilothermia. Even with a nutritionally adequate diet they failed to gain weight. None of this severely affected group survived infancy. Some patients with semilobar holoprosencephaly, however, will survive into childhood but will be mentally defective. Patients with lobar holoprosencephaly may reach adulthood and have normal mentality but many, if not most, will also be mentally defective.

Case reports

Case 1. S. O. was a 3 month old female with microcephaly (Fig. 2). The occipito frontal circumference was 27.5 cm. Physical examination revealed that her palpebral fissures had a distinct mongoloid tilt. She had orbital hypotelorism with clinical evidence of trigonocephaly which consists of a keel shaped forehead, orbital hypotelorism and supraciliary depression extending *laterally to the temples. Because of a median cleft of her upper lip, gum, primary* and secondary palates, the nasal and oral cavities communicated. The nasal septum was absent.

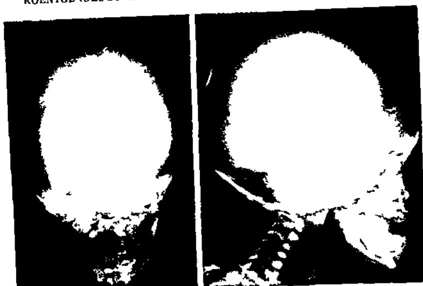


Fig 6 Case 3 Frontal and lateral skull roentgenograms indicate orbital hypotelorism Nasal and median facial bones are absent N so-gastric tube (arrow) rests on the palatine processes of the maxillary bones which form the secondary palate Primary palate is absent in median cleft facial type

Roentgenograms of the skull and face in frontal and lateral projections indicate absence of the nasal bones and extreme orbital hypotelorism (Fig 3) The vomer perpendicular plate of the ethmoid and the crista galli are absent The cranial sutures including the metopic are open and the maxillae and mandible are hypoplastic the former to a more severe degree The skull is small particularly in the region of the anterior cranial fossa The soft tissues of the shallow bony orbits protrude anteriorly Two small frontal bones are present At necropsy an alobar holoprosencephalon was found which was very small compared to the intracranial volume (Fig 4) It was attached to the region of the posterior fontanelle leaving fluid filled spaces in front and behind The space between the holotelencephalon and the cerebellum was occupied by the dorsal sac which was completely separate from the space in front The metopic suture was open in its entirety

Comment It is evident from this case that closure of the metopic suture is not essential for the presence of trigonocephaly (ref 10)

Case ? J \ was a 3 week-old male with microcephaly (Fig 8) The occipito-frontal circumference was 31 cm Physical examination indicated orbital hypotelorism with a median cleft lip and a united secondary palate There was no trigonocephaly A chromosome study indicated an apparently normal 46 chromosome karyotype Roentgenograms in frontal and lateral projections indicate marked orbital hypotelorism (Fig 5) The cranial sutures are open The nasal bridge is flat and the soft tissues of the shallow bony orbits are protruding anteriorly The nasal and vomer bones are absent and the ethmoidal labyrinths are hypoplastic The crista galli is not identified The palatine processes of the maxillary bones are fused in the midline The anterior cranial fossa and frontal bones are small Necropsy disclosed an alobar holoprosencephalon

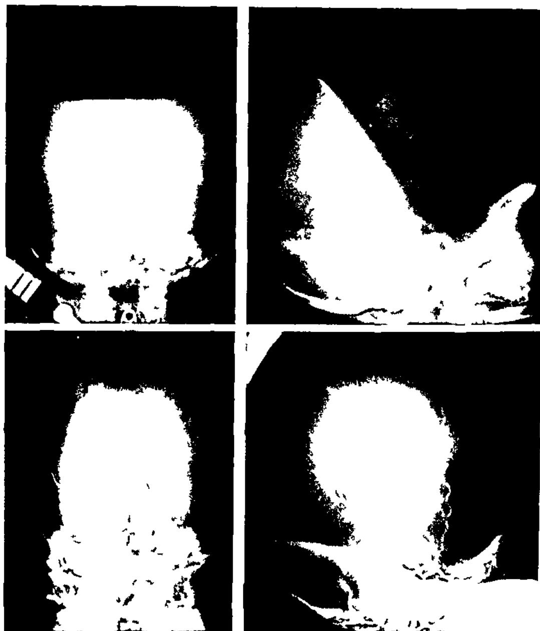


Fig. 7. Case 3. Ventriculograms in frontal and lateral projections (above) indicate large space anterior to the cerebral mantle and the posterior dorsal sac. Carotid arteriograms (below). Arteries around brain substance are middle cerebral and possibly anterior cerebral arteries.

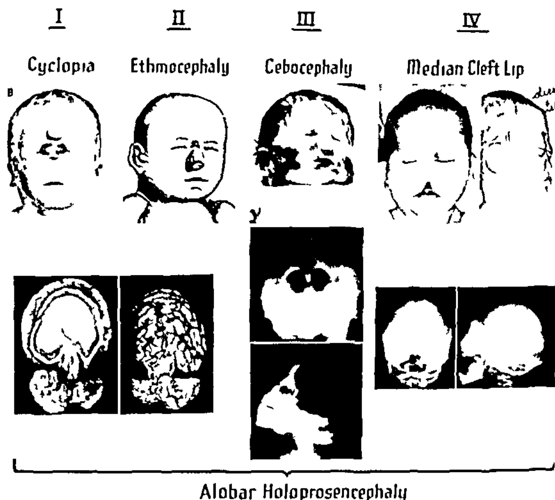
Case 3 A H was a 6-month-old female with an occipito-frontal circumference of 40 8 cm Physical examination indicated orbital hypotelorism with a wide median cleft in the upper lip and gum The secondary palate was intact and the orbital fissures had a mongoloid tilt There was no trigonocephaly The nasal septum was absent Roentgenograms in frontal and lateral projections at one week of age indicate marked orbital hypotelorism (Fig 6) The crista galli is not seen The vomer and nasal bones as well as the perpendicular plate of the ethmoid bone are absent The ethmoidal labyrinths are hypoplastic as are the maxillae The palatine processes are fused in the midline Orbital soft tissues protrude from the shallow bony orbits The cranial sutures are open and two small frontal bones are present The anterior cranial fossa is small Ventriculography and arteriography performed at six months of age outline the cerebral mantle with the large dorsal sac posterior and above the tentorium cerebelli (Fig 7) A large volume of fluid occupies the space anterior to the holoprosencephalon Necropsy confirmed the presence of an alobar holoprosencephalon

Comment Cases 2 and 3 had the characteristic clinical features of median cleft lip Although the median facial bones derived from prechordal mesoderm were defective the secondary palate derived from fusion of the laterally originating palatine processes of the maxillary bones was intact Apart from this interesting difference the roentgen craniofacial configurations were almost identical in the first 3 patients

Case 4 R was a white male infant who died 9 hours after delivery by caesarean section (Fig 8) The occipito frontal circumference was 27 5 cm Physical examination indicated a rudimentary nose with a single median nostril The lip was united in the midline but without a distinct philtrum The only extracephalic malformations were single transverse palmar creases and undescended testicles Chromosome studies from a skin culture disclosed an apparently normal 46 chromosome karyotype Roentgenograms of the skull were done after removal of the brain and calvaria There was marked orbital hypotelorism with a nasal space wedged between the orbits The maxillae were hypoplastic and fused in the midline The nasal bones were absent but hypoplastic osseous components (ethmoid) were present in the interorbital space The brain malformation as seen at postmortem was that of alobar holoprosencephaly No thoracico-abdominal visceral malformations were present

Comment Case 4 had typical cebocephalic facies The roentgen craniofacial configuration was most interesting with a rudimentary nasal space wedged between two orbits which were very close together The maxillae were fused in the midline and there was microcephaly Cases 1 through 4 had strikingly similar brain malformations of alobar holoprosencephaly

Case 5 M D was a 4 month-old female with microcephaly The occipito-frontal circumference was 28 5 cm There was minimal clinical evidence of trigonocephaly Physical examination indicated bilateral lateral clefts of the lip and primary palate with a median process philtrum premaxilla anlage or intermaxillary segment) extending from the region of the upper lip to the uvula This median process continued upward as the nasal septum and could be seen extending to the posterior wall of the pharynx with which it united Chromosome studies of the peripheral blood and skin from the median process disclosed an apparently normal 46 chromosome karyotype During the latter months of life a single incisor tooth erupted from the median process establishing that a premaxilla anlage was present Skull roentgenograms in frontal and lateral projections outline the median process and the unerupted single incisor Fig 8 The anterior cranial fossa is small as are the frontal bones Nasal bones and a midline septum are visible Postmortem study of the brain indicated lobar holoprosencephaly type A see Table



For legend see opposite page

Comment Case 5 had a more advanced degree of median facial development with nasal bones a nasal septum primitive philtrum and premaxilla (philtrum premaxilla anlage) with a single central incisor which was unerupted at the time of roentgen examination Correspondingly there was a more advanced degree of brain development — lobar holoprosencephaly (type A see Table) (ref 7)

Case 6 S D was a 5 1/2 week old male with facial features suggestive of cebocephaly The occipito frontal circumference was 28 cm There was no clinical evidence of trigonocephaly Physical examination revealed the upper lip to be united in the midline but without a distinct philtrum There was a rudimentary nose and a single aperture to the nasal cavity There was no cleft palate The eyes were prominent Frontal and lateral skull roentgenograms indicated microcephaly The orbits were shallow and the protruding orbital soft tissues were seen in the lateral projection The anterior cranial fossa was small Small nasal bones were identified but the nasal bridge was flat There was orbital hypotelorism A midline osseous structure was seen in the frontal projection probably representing the perpendicular ethmoid

V
Philtrum
premaxilla anlage





Lobar Holoprosencephaly

Fig 8 Composite clin cal roentgen and neuroanatom c features of holoprosencephaly Roentgenograms and anatomic specimens not necessar ly those of patients dep cted

B ain in lower left is prototype of alobar holoprosencephaly Cavity in dorsal view (left) represents single ventricle of the cerebrum Corpora striata and thalami are uncleft in the midline Ventral view (right) ndicates absence of olfactory bulbs and tracts but all other cranial nerves intact

Brain in column V is lobar holoprosencephaly type A Interhem spher c fissure extends only to frontal lobes wh ch are fused Falx cerebri present posteriorly only Absence of olfactory bulbs and tracts

Case 2 Median cleft lip fac al type is seen heading col umn IV (Reproduced by perm ssion from Archives of Neurology)

Case 1 Cebocephaly is seen heading column III (Reproduced by permiss on from Ann Paediat S Karger Basel/New York)

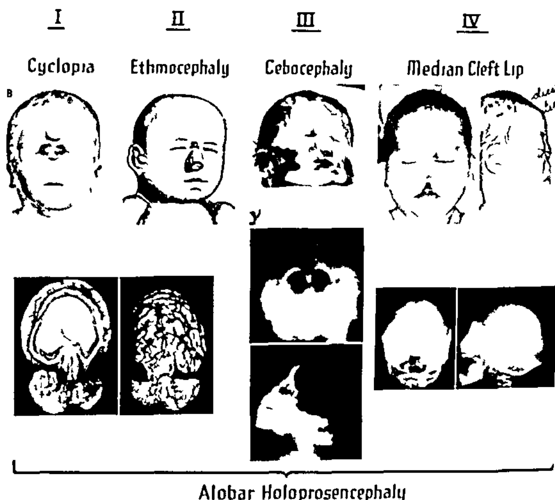
Case 5 Roentgenograms in column V indicate median process w th sol tary unerupted incisor seen in slightly obl que frontal projection Nasal bones evident in the lateral projection

plate and perhaps the vomer The other portions of the ethmoid bone including the conchae were hypoplastic as *were the maxillae* The cranial sutures were open At postmortem this patient had lobar holoprosencephaly type A No extracephalic anomalies were present

Comment Case 6 is interesting in that clinically the facial features suggested cebocephaly with a rudimentary nose and a single nasal aperture There was no distinct philtrum present in the upper lip The roentgen features of the face however indicated the presence of nasal and median facial bones suggesting a more advanced degree of median facial development than anticipated in true cebocephaly The brain malformation lobar holoprosencephaly type A corresponded with the more advanced degree of facial bone development indicated by the roentgenograms

Discussion

The majority of the seventeen cases of holoprosencephaly in this series were of the median cleft lip facial type One case of cebocephaly was encountered



For legend see opposite page

Comment Case 5 had a more advanced degree of median facial development with nasal bones a nasal septum primitive philtrum and premaxilla (philtrum premaxilla anlage) with a single central incisor which was unerupted at the time of roentgen examination Correspondingly there was a more advanced degree of brain development — lobar holoprosencephaly (type A see Table) (ref 7)

Case 6 S D was a 5 1/2 week old male with facial features suggestive of cebocephaly The occipito frontal circumference was 28 cm There was no clinical evidence of trigonocephaly Physical examination revealed the upper lip to be united in the midline but without a distinct philtrum There was a rudimentary nose and a single aperture to the nasal cavity There was no cleft palate The eyes were prominent Frontal and lateral skull roentgenograms indicated microcephaly The orbits were shallow and the protruding orbital soft tissues were seen in the lateral projection The anterior cranial fossa was small Small nasal bones were identified but the nasal bridge was flat There was orbital hypotelorism A midline osseous structure was seen in the frontal projection probably representing the perpendicular ethmoid

associated with holoprosencephaly A continuing study is in progress at this institution using laminography of the face and skull to aid in this differentiation

Chromosome studies suggest that the holoprosencephalies fall into two groups Both are similar or identical in the craniofacial malformations but differ in respect to the extracephalic anomalies One group has a minor or perhaps one major extracephalic anomaly The second group is associated with multiple severe extracephalic anomalies such as malformations of the heart and gastro intestinal tract The karyotype of Group 1 has been studied in a very limited number of patients and found to consist of the normal number of chromosomes Group 2 on the other hand may have an additional chromosome of the 13/15 or D group It appears that the brain malformation can be predicted from the facial configuration regardless of the karyotype (ref 3, 6) Further chromosome studies will be necessary to confirm this hypothesis

SUMMARY

Median defects of the face and skull are strongly associated with a brain malformation characterized by incomplete division of the prosencephalon into cerebral hemispheres A teratologic series can be recognized which when arranged in decreasing order of severity includes five distinct facial types 1 Cyclopia 2 Ethmocephaly 3 Cebocephaly 4 Median cleft lip and 5 Philtrum premaxilla anlage Roentgenographic features characteristic of this series include orbital hypotelorism and absence or marked hypoplasia of the median facial structures and crista galli

ZUSAMMENFASSUNG

Mediane Defekte des Gesichtes und Schadels sind haufig von Gehirnmissbildungen begleitet Diese sind dadurch *charakterisiert dass sich das* Prosencephalon unvollständig in die Hemisphären teilt Man kann eine teratolog*ische Serie* erkennen die bei Reihung nach abfallenden Schweregrad 5 Typen umfasst 1) *Cyklopie* 2) Ethmocephalie 3) mediane Lippenspalte 4) Philtrum Praemaxillaanlage Rontgen*merkmale die* fur diese Serie charakteristisch sind inkludieren orbitalen Hypotelorismus und *Fehlen oder bedeutende* Hypoplasie der medianen Gesichtsstrukturen und crista Galli

RÉSUMÉ

Les malformations médianes de la *face et du* crane sont en corrélation étroite avec une malformation cérébrale caractérisée *par une division* incomplète du prosencéphale en hémisphères cérébraux On peut établir une *série* tératologique qui comprend rangés par gravité décroissante cinq types faciaux distincts 1 *Cyclopie* 2 Ethmocéphalie 3 Cébocéphalie 4 Bec-de-liè*vre* médian et 5 ébauche *philtro-prémaxillaire* Les signes radiologiques caractéristiques de cette série comprennent l hypotél*orisme* orbitaire et l absence ou l hypoplasie marquee des structures médianes de la face et de la crista galli

and no cases of cyclopia or ethmocephaly. All patients with the median cleft lip facial type and the one case of cebocephaly had the severe brain malformation of alobar holoprosencephaly.

The roentgen findings in median cleft lip facial type include microcephaly, orbital hypotelorism, absence or marked hypoplasia of the median facial bones including the vomer, ethmoid, nasal, premaxilla, and primary palate as well as the nasal septum. The presence of this group of roentgen findings permits the diagnosis of alobar holoprosencephaly and the prognosis of almost certain death within the first year of life (ref. 7). Associated roentgen findings include maxillary bone hypoplasia, shallow orbits with protruding orbital soft tissues, and high orbital roofs with a small anterior cranial fossa and small frontal bones. The longest diameter of the orbits in the frontal projection may be oriented vertically or supero-medially and the superior orbital margins may be semi-circular ('half-moon orbits') in configuration (ref. 1).

Alobar holoprosencephaly is almost always associated with microcephaly, except under the unusual circumstances of a large dorsal sac with a large intracranial fluid volume as seen in Case 3 of this series.

Defective development of the median facial structures and the orientation and configuration of the orbits serve to differentiate patients with microcephaly and alobar holoprosencephaly from other microcephalic patients. In the absence of median facial defects the half-moon configuration of the superior orbital contour and the vertical orientation of the longest diameter in the frontal projection help to differentiate patients with microcephaly and hypotelorism from those without hypotelorism. Interorbital distance measurements in infants and children have been obtained based on posteroanterior skull roentgenograms believed to be normal (ref. 2). This scale of measurements relates interorbital distance to age. In the presence of microcephaly, however, these measurements must be applied with great caution.

WELCKER who first named trigonocephaly more than a century ago recognized two types: 1) the simple cranial deformity with no other associated median facial and presumably no brain malformation and 2) the complex form associated with other median facial defects and holoprosencephaly (arhinencephaly) (ref. 12). Patients with the mild form of holoprosencephaly may be *normal externally or may have trigonocephaly*. It is in this latter group that careful evaluation of the midline facial structures may be useful in differentiating simple trigonocephaly from the complex form associated with brain malformations which are not evident clinically. Defective development of the midline components of the ethmoid bone (crista galli and perpendicular plate), vomer, premaxilla, primary palate, nasal bones and nasal septum may serve as a *means of differentiating simple trigonocephaly from trigonocephaly*

FROM THE DEPARTMENTS OF PATHOLOGY RADIOLOGY AND NEUROSURGERY, YALE UNIVERSITY SCHOOL OF MEDICINE, NEW HAVEN, U S A

THE CRANIOPHARYNGEAL CANAL

by

R M LOWMAN F ROBINSON and W B McALLISTER

The craniopharyngeal canal arises superiorly in the mid portion of the floor of the hypophyseal fossa and when complete may extend inferiorly to terminate behind the rostrum of the sphenoid between the alae of the vomer Described by a variety of names i e basipharyngeal or basioccipital canal, the nature of this structure has been controversial One thesis backed by tradition purports the canal to be the pathway of transmission of the buccal hypophyseal diverticulum i e the pathway of the former stalk of Rathke s pouch Another view maintains that this structure *represents* remnants of a vascular channel formed during osteogenesis by fetal vessels

During the course of study of hypophyseal embryogenesis and suprasellar tumors a completely patent craniopharyngeal canal was encountered in a disarticulated skull in the department of anatomy (Figs 1 and 2) The following studies were undertaken to investigate the nature of this canal and why it may persist for a short time or permanently

1 Anatomic studies of the sub human primates and lower mammalian skulls were made

2 Studies were made of disarticulated sphenoid bones and human skulls in the Department of Anatomy of the Yale University School of Medicine

3 Sagittal sections of the sphenoid regions of the skulls of stillborn prematures

REFERENCES

1 ANDERSON F M GWINN J L and TODT J C Trigonocephaly Identity and surgical treatment J Neurosurg 19 (1962) 723

2 CURRARINO G and SILVERMAN F N Orbital hypotelorism arhinencephaly and trigonocephaly Radiology 74 (1960), 206

3 DEMYER W A 46 chromosome cebocephaly with remarks on the relation of 13—15 trisomy to holoprosencephaly (arhinencephaly) Ann Paediat 203 (1964) 169

4 — and WHITE P The electroencephalogram in holoprosencephaly (arhinencephaly) Arch Neurol 11 (1964) 507

5 — and ZEMAN W Alobar holoprosencephaly (arhinencephaly) with median cleft lip and palate clinical electroencephalographic and nosologic considerations Confin neurol 23 (1963) 1

6 — — and PALMER C Familial alobar holoprosencephaly (arhinencephaly) with median cleft lip and palate Neurology 13 (1963) 913

7 — — — The face predicts the brain diagnostic significance of median facial anomalies for holoprosencephaly (arhinencephaly) Pediatrics 34 (1964) 256

8 LONGMAN J Medical embryology p 303 Williams & Wilkins Baltimore 1963

9 METTLER F A Congenital malformations of the brain J Neuropath exp Neurol 6 (1947) 98

10 RIEMENSCHNEIDER P A Trigonocephaly Radiology 68 (1957) 863

11 STARK R B and EHRMANN N A The development of the center of the face with particular reference to surgical correction of bilateral cleft lip Plast reconstr Surg 21 (1958) 177

12 WELCKER H Untersuchungen uber Wachsthum und Bau des menschlichen Schadels p 120 Verlag Von Wilhelm Engelmann Leipzig 1862



Fig 2 Lateral film of a disarticulated sphenoid bone with a thin metal probe inserted to show the course of the canal shown in fig 1 The canal was not visible on conventional lateral films

basilar surface of the sphenoid approximately at the junction where the wings of the vomer meet the body of the sphenoid bone The lower opening of the canal in this area may vary in shape AREY has described a specimen with an elongated funnel shaped foramen in this area which measured 2 0 mm in its greatest diameter Canals of larger size have also been described Blind canals may extend into the body of the sphenoid bone from one or both surfaces of this bone ranging from tiny pits to passages sometimes 5 0 mm long

The contents of the canal have been studied in an attempt to evaluate the character of this structure The contents have been described as (1) connective tissue continuous with the dura and the periosteum (2) a vein opening into the cavernous sinus above and into a longitudinal periosteal vein below, (3) an artery has been described entering the sphenoid bone and studies made of cat specimens and in addition (4) DRAGER (1944) has described nerve bundles arising from the internal carotid plexus which were distributed to the blood vessels within the sphenoid bone in sections made from cats

The description of the vascular constituents of the human craniopharyngeal canal is based on studies of injected fetuses made by ARAI (1907) In addition to the structures described above other authors have described accessory hypophyseal tissue in the canals Hypophyseal tissue within the open canal itself HABERFELD 1909) as well as pituitary tumors within the body of the sphenoid have been reported (GARSCHIN 1930)

Methods of study and observations

A fund of information concerning the occurrence of the craniopharyngeal canal in the sub-human primates and lower mammals exists The canal was found in 37 % of 321 anthropoid apes studied In chimpanzees a previous canal occurred in 64 % of the specimens (CAVE 1931) Other observers have noted

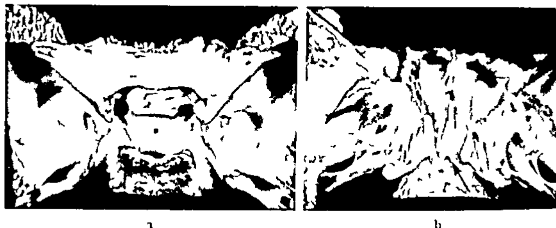


Fig. 1. a) Photograph of upper surface of an adult disarticulated sphenoid bone showing upper end of craniopharyngeal canal in the hypophyseal fossa. b) Lower opening of the craniopharyngeal canal.

and full term fetuses were examined to determine whether or not residual canals or related structures could be identified.

4. Roentgenologic and histologic studies were made of the sphenoid bones of rabbits and cats.

5. The incidence of occurrence of the craniopharyngeal canal in approximately 100 skull films or newborn fetuses was evaluated.

Various investigators have studied the frequency of occurrence of this canal in varying human age groups. Early descriptions of the canal were recorded by HENLE (1855), VIRCHOW (1857) and LANDZERT (1868). The studies of specimens beyond the age of infancy and the frequency of occurrence of the craniopharyngeal canal have been summarized (AREY 1950, CAVE 1931, SOKOLOW 1904, MAGGI 1890 and CITELLI 1913). AREY noted that the channel occurred at the rate of one specimen in 238 human skulls examined (0.42 %). The recorded incidence of complete craniopharyngeal canal is 35 out of 8 338 skulls studied. In addition, various observers have pointed out that incomplete canals occurred in this area far more commonly than complete canals. The length of the blind canals extending into the sphenoid bone varies. Closure of a canal tends to proceed progressively from below upwards. Pits occurring on the floor of the hypophyseal fossa were considered the last trace of a former previous canal (Fig. 3).

The proximal aperture of the canal may vary from a circular to an oval outline in the midplane of the deepest part of the sella. The oval foramen measures from 1.0 to 1.5 mm in diameter. The canal, when completely patent, extends downward and backward for a distance of 15 to 16 mm, and emerges on the

formalin solution and then decalcified by overnight immersion in Decal The blocks were washed in tap water for 24 hours and after immersion in 50 % alcohol for 24 hours the blocks were trimmed to a thickness of 5 mm and embedded in Paraplast in the normal manner

Serial sections were then cut from the embedded tissue and each time 20 sections were cut the six subsequent sections were mounted on glass slides for staining Thus sections 20 through 26 40 through 46 60 through 66 were available for staining Prior to sectioning roentgenographic studies were made of the midline sagittal sections to determine if patent craniopharyngeal canals could be demonstrated (Fig 5) Observations were then made on the sections from these blocks of the sphenoid bone to determine the presence of the craniopharyngeal canal The adjacent structures such as the hypophysis the hypothalamus the blood vessels nerves and pharyngeal tissues were likewise studied Appropriate stains i e hematoxylin eosin Masson and the Weigert s myelin stain to demonstrate the tissues and nerve fibers in this area were made The study of the sphenoid bone in the group of cat skulls examined, revealed the presence of a well defined canal in every specimen The canal appeared to be surrounded by a layer of compact bone and extended from the floor of the hypophyseal fossa through the posterior margin of the sphenoid bone to the pharyngeal surface of the skull In some of the cases the canal did not completely extend to the pharyngeal surface of the sphenoid bone At the sellar entrance a strand of connective tissue was noted to continue with the sellar capsule and periosteum through the canal toward the inferior surface of the body of the sphenoid The canal contained a relatively large vein and a rather small artery Tributaries of these vessels appeared to arise in the sphe noid bone and merged to form the larger vessels (Fig 7) The majority of the vessels were apparently derived from the internal carotid plexus extending from the circle of Willis into the hypophyseal capsule No definite demonstra tion of nerve fibers accompanying the larger arterial branches within the sphenoid bone were shown using the routine stains for myelin

During the period 1960 to 1964 an unselected group of stillborn fetuses were obtained Lateral skull films of the fetuses prior to postmortem studies were obtained In 25 of the fetuses the sphenoid bones were completely removed and sagittal midline sections of the sphenoid bone containing the sella turcica were completed This portion of the bone was divided in its center and sec tions were made from both margins of the blocks in an attempt to define the structures in this area The sections were stained with hematoxylin and eosin No attempt to dissect the posterior aspects of the sella turcica were made at this time In addition roentgenographic magnification as well as routine views were made in some cases in an attempt to define the presence of a craniopharyn

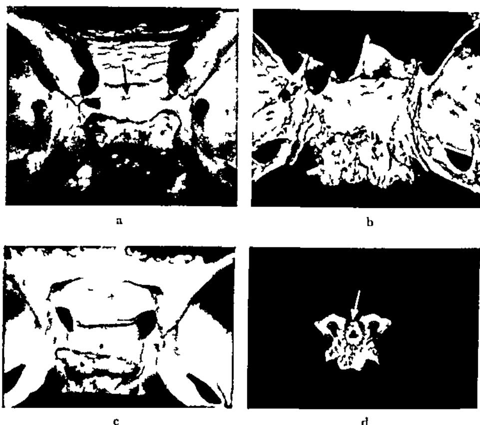


Fig 3 a) Photograph showing upper end of an incomplete craniopharyngeal canal Small pits in posterior portion of hypophyseal fossa b) Multiple pits are visible in the floor of the hypophyseal fossa c) A large antral pit on the floor of the hypophyseal fossa and smaller pits in the anterior portion of the fossa and region of the tuberculum d) Photograph of a sphenoid bone of a newborn A large completely patent craniopharyngeal canal

the constant recurrence of the canal in cats and rabbits (MAGGI 1893, DRAGER 1944) An examination of a wide range of mammalian skulls in the Peabody Museum collection of the Yale University revealed openings in the floor of the pituitary fossa which in some instances were continuous and could be traced by probe to extend to the under surface of the skull to the vomero sphenoid junction

Our observations confirm the persistent presence of the canal as a constant feature in the rabbit and the cat in the skull collection of the Museum Further studies were then undertaken of cat and rabbit skulls The severed heads of these animals were frozen to minus 10° C and sectioned in the vertical sagittal plane by band saw while still frozen solid The resulting section containing all of the midline structures was approximately 8 to 10 mm in thickness The section containing this tissue was fixed for 24 hours in buffered 10 %

formalin solution and then decalcified by overnight immersion in Decal The blocks were washed in tap water for 24 hours and after immersion in 50 % alcohol for 24 hours the blocks were trimmed to a thickness of 5 mm and embedded in Paraplast in the normal manner

Serial sections were then cut from the embedded tissue and each time 20 sections were cut, the six subsequent sections were mounted on glass slides for staining Thus, sections 20 through 26 40 through 46 60 through 66, were available for staining Prior to sectioning roentgenographic studies were made of the midline sagittal sections to determine if patent craniopharyngeal canals could be demonstrated (Fig 5) Observations were then made on the sections from these blocks of the sphenoid bone to determine the presence of the craniopharyngeal canal The adjacent structures such as the hypophysis the hypothalamus the blood vessels, nerves and pharyngeal tissues were likewise studied Appropriate stains, i e hematoxylin eosin, Masson and the Weigert s myelin stain to demonstrate the tissues and nerve fibers in this area were made The study of the sphenoid bone in the group of cat skulls examined revealed the presence of a well defined canal in every specimen The canal appeared to be surrounded by a layer of compact bone and extended from the floor of the hypophyseal fossa through the posterior margin of the sphenoid bone to the pharyngeal surface of the skull In some of the cases the canal did not completely extend to the pharyngeal surface of the sphenoid bone At the sellar extrance a strand of connective tissue was noted to continue with the sellar capsule and periosteum through the canal toward the inferior surface of the body of the sphenoid The canal contained a relatively large vein and a rather small artery Tributaries of these vessels appeared to arise in the sphe noid bone and merged to form the larger vessels (Fig 7) The majority of the vessels were apparently derived from the internal carotid plexus extending from the circle of Willis into the hypophyseal capsule No definite demonstra tion of nerve fibers accompanying the larger arterial branches within the sphenoid bone were shown using the routine stains for myelin

During the period 1960 to 1964 an unselected group of stillborn fetuse were obtained Lateral skull films of the fetuses prior to postmortem studies were obtained In 25 of the fetuses the sphenoid bones were completely removed and sagittal midline sections of the sphenoid bone containing the sella turcica were completed This portion of the bone was divided in its center and sec tions were made from both margins of the blocks in an attempt to define the structures in this area The sections were stained with hematoxylin and eosin No attempt to dissect the posterior aspects of the sella turcica were made at this time In addition roentgenographic magnification as well as routine views were made in some cases in an attempt to define the presence of a craniopharyn

geal canal. In none of the lateral conventional films was a definite craniopharyngeal canal visible. The studies of the stained sections of the sphenoid bone and the adjacent pituitary structures, however, demonstrated large vascular channels arising superiorly and inferiorly in the body of the sphenoid bone which extended into this structure. While large vascular channels were demonstrated in the region of the sphenoid bone which simulated those described in the cat, a large gross definite channel was not distinguished in any of the cases. However, large vessels arising from the margins of the sellar capsule extending into the region of the sphenoid bone could be demonstrated (Fig. 8).

A review of the collection of skulls in the Department of Anatomy of the Yale University School of Medicine showed one infant skull which had a prominent complete canal (Fig. 3 d). One adult sphenoid bone also demonstrated a complete canal. While the canal was not visible in the routine film the insertion of a wire probe (Fig. 2) demonstrated its course. Several skulls demonstrated incomplete canals which were more common than the completely patent canals (Fig. 3). In other specimens blind pits were demonstrated to extend for several millimeters leading from one or both surfaces of the skull into the body of the sphenoid bone. The number of skulls surveyed was limited and therefore insufficient to provide a valid statistical conclusion. The description of the craniopharyngeal canal and the sellar pits is similar to that which has been noted previously.

The lateral films of 400 newborn skulls were completed and reviewed. Detailed examination of these films revealed a fine line which traversed the body of the sphenoid bone in the non pneumatized fetal sphenoid in two cases (Fig. 4, a and b). An incomplete line was demonstrated in an additional 2 cases. This thin line was thought to represent the craniopharyngeal canal. The passage of fine vascular markings over the margins of the sella and the sphenoid bone rarely presented problems and were readily differentiated with the aid of a magnifying hand lens. By contrast, the synchondrosis between the presphenoid and the postsphenoid, in addition to the spheno occipital synchondrosis were frequently seen. The synchrondrosis between the presphenoid and postsphenoid or basisphenoid and portions of the body of the sphenoid bone, i.e. the inter sphenoidal synchondrosis, occasionally presented the appearance of a canal in the anterior portion of the pituitary fossa. When the articulation between the pre- and postsphenoid segments of the sphenoid bone was demonstrated in properly exposed films it measured 0.5 to 1.0 mm in width and 5.0 mm in length. The anterior superior portion of the synchondrosis terminated just anterior to the margins of the anterior clinoid processes. This synchondrosis was always more sharply defined than the thin line seen in the mid portion of the sphenoid bone. The differentiation of the spheno

occipital synchondrosis posteriorly posed no problem and was seen in all of the cases studied

The thin line which was demonstrated in two of the cases, and partially in another two cases, was thought to represent the craniopharyngeal canal or a remnant of this structure It is also possible that this represents the larger vascular channel demonstrated in the histological sagittal sections Whenever demonstrated it was situated several millimeters posterior to the intersphenoidal synchondrosis It arose approximately in the midportion of the sellar floor and extended inferiorly for a distance of 3 to 5 mm toward the base of the skull Although the inferior margins could be outlined by air in the epipharyngeal area the lower portion of the line in this region was obscured In one case there appeared to be areas of minimal marginal sclerosis delineating the lateral borders of the canal The anterolateral temporal fontanel presented no difficulties in differential diagnosis In addition however one must be certain that the overlapping of the linear lines produced by the vascular grooves traversing the anterior portion of the squamous segment of the temporal bone are not mistaken for a persistent craniopharyngeal canal An anterior branch of the middle temporal artery may produce a similar line in this area on the external skull surface Meningeal arterial vascular grooves on the endosteal aspect of the skull may occasionally present problems The coursing of the vessel beyond the margins of the sphenoid bone will aid in differentiation of such vascular grooves

In addition routine and special skull film studies in 25 cases of craniopharyngioma were reviewed and examined from the department of neurosurgery In one of these were structures which could be construed or identified as representing a patent craniopharyngeal canal In none of the cases examined were craniopharyngiomas found within the margins of the sphenoid bone itself

Discussion

The demonstration of the craniopharyngeal canal and the sellar pits have prompted this study in an attempt to determine the character of these structures The rare and infrequent comments on the craniopharyngeal canal in the roentgenographic texts indicate that the craniopharyngeal canal has been passively accepted as the pathway transmitted by Rathke s pouch (CAFFEY 1950 DYKE 1918 KOHLER & ZIMMER 1956 SHAPIRO & JANZEN 1960) The Radiographic demonstration of the canal in the base view of the skull was proposed by DYKE in 1948 but anatomic confirmation of this finding was not forthcoming Our own radiographic attempts which have included the routine positions laminographic stereoscopic views in addition to magnification views

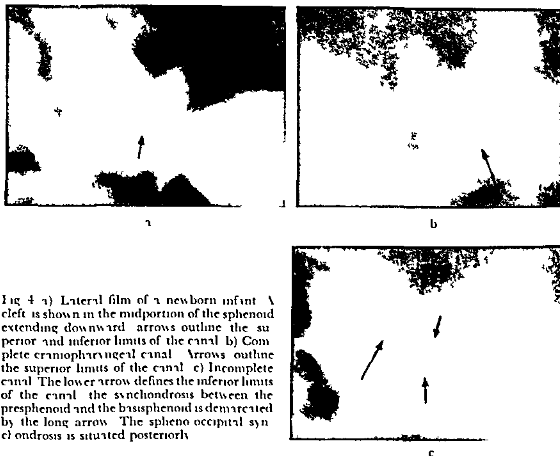


Fig. 4 a) Lateral film of a newborn infant. A cleft is shown in the midportion of the sphenoid extending downward; arrows outline the superior and inferior limits of the canal. b) Complete craniopharyngeal canal. Arrows outline the superior limits of the canal. c) Incomplete canal. The lower arrow defines the inferior limits of the canal; the synchondrosis between the presphenoid and the basisphenoid is demarcated by the long arrow. The spheno-occipital synchondrosis is situated posteriorly.

have indicated that neither the pits nor the canal are to be defined in the adult skull. Thus far, we have not encountered a patent craniopharyngeal canal in the base view studies. Detailed roentgenographic studies were made on dried skulls following the drilling of 1.0 and 2.0 mm holes through the sellar floor to demonstrate the difficulties in demonstrating the channel. At no time was the canal shown in the lateral views. Moreover, the demonstration of the drilled channels in the base view required special positioning to project the long axis of the canal end on. Though the canal occurs with high incidence in the sphenoids of various mammals, this structure was not shown using the routine radiographic techniques. The histologic studies of the newborn skulls confirmed the presence of vascular channels which could simulate the course of the craniopharyngeal canal. These channels were encountered frequently in the studies of the sagittal sections of the fetal skulls. Studies of these sections at the same time did not reveal any evidences of proliferative nests of squamous or ciliated epithelium or aberrant epithelial anlagen.

The development and the constituents of human hypophyseal embryo



Fig 5 a) Lateral film of a section of a cat's skull prepared by sectioning the midportion of the skull after freezing A 1 5 cm sagittal section containing the midline structures was then cut by a band saw Although a completely patent canal is present it is not visible in this film b) Lateral film of sagittal section of a rabbit's skull prepared from a midline segment cut following freezing This contained all the midline structures Prominent spheno-occipital synchondrosis posteriorly (Histologic sections showed a craniopharyngeal channel in the midportion of the sphenoid bone)

genesis were exhaustively studied by TILNEY (1936) The hypophysis cerebri is derived embryologically from two separate ectodermal structures the neuroectodermal prolongation from the floor of the primitive forebrain and the ectodermal lining of the primitive stomodeum or the mouth cavity The latter known as Rathke's pouch gives rise to the anterior lobe or the adenohypophysis whereas the neuroectodermal diverticulum gives origin to the posterior lobe and the infundibulum It was TILNEY's observation that the craniopharyngeal duct ceased to exist in early embryonic forms and that this structure initially represented a transient communication between the mouth cavity and the pituitary pouch becoming a solid stalk which later disappeared ARE\ has pointed out that the elongation and narrowing into a slender stalk and the subsequent disappearance of this stalk begins at 6 weeks (12 0 mm embryo) and is usually obliterated at 8 weeks (23 0 mm embryo) in the future sphenoidal region Variations of the obliteration of this duct were noted TILNEY concluded that no substantial proof existed to support the view that the embryonal hypophyseal duct or attenuated stalk persists into adult life in the human He suggested that there was little to favor the continued use of the term craniopharyngeal duct

In order critically to assess the sphenoidal channel it is necessary to correlate the development of the cartilage bone and blood vessels of the basisphenoidal



Fig 6 a) Sagittal section through pituitary and midportion of the sphenoid of a rabbit The section is just to the one side of the midline and does not completely show the posterior lobe of the pituitary gland A large thin walled venous channel runs in the pituitary capsule down to join a thin walled triangular venous lake in the midportion of the sphenoid bone b) Midline section from same animal showing the venous lake The posterior lobe of the pituitary is better shown 1 — Synchondrosis between pre and postsphenoid 2 —spheno-occipital synchondrosis 3 — venous lake in midportion of sphenoid A channel connects this to venous channels shown at the inferior margins of the pituitary gland

area The studies by AREY (1950) and MALL (1906) indicate that concurrent with the disappearance of the stalk of Rathke's pouch, there is chondrification of the sphenoid Precartilage changing into cartilage within the body of the sphenoid was shown in the 17 mm embryo A canal marking the location of the former stalk could no longer be identified in embryos of 33, 37, 55 up to 255 mm MALL (1906) using cleared specimens demonstrated paired ossification centers in 70 mm embryos and showed that these were united at 105 mm Thus, in terms of time, the paired sphenoid ossification centers appear at approximately 13 weeks and unite at 16 weeks Primitive marrow formation with conversion of cartilage into spongy bone was shown in the 110 mm length embryo

The studies of the sagittal sections of the cat, rabbit and human sphenoid bones presented significant information on the vascular structures of this area Blood vessels were seen to course lengthwise along the curved depth of the hypophyseal fossa adjacent to the perichondrium of the sphenoid bone In several sections, large prominent vessels were noted beneath the margins of the hypophysis These arose in the region of the sellar capsule and extended downward into the sphenoid bone Other sections studied demonstrated a central vascular channel pressing directly downward from the lowest point of the hypophyseal fossa and penetrating the body of the sphenoid bone (Figs 6, 7, and 8) The central canal appeared to connect laterally with other smaller vascular channels In one section at least, vessels beneath the sphenoid bone had extended into the peripheral spongy bone



Fig 7



Fig 8

Fig 7 Midline section from a cat The bony canal is evident Thin walled venous channels are seen in the pituitary capsule and they *communicate through this channel* inferiorly Several tiny acini structures lined by cuboidal epithelium and containing a minute amount of colloid like substance which histologically are much like the middlobe of the pituitary are also seen The venous channel in this case is surrounded by cancellous bone

Fig 8 Midline section through a full term stillborn *human fetus* A *large thin walled venous* channel runs in the capsule of the pituitary Such channels communicate with large tortuous venous *sinusoids in the midportion of the sphenoid bone*

Thus the channel follows the same topographical course along which the elongating stalk of Rathke s pouch is directed It is unlikely however that this channel *represents the canal through which in early fetal life the hypo* physeal diverticulum of the buccal ectoderm is transmitted The evidence indicates that this residual canal is neither the remnants of the hypophyseal *stalk nor the residuum of the space formed by the degenerating hypophyseal* stalk Moreover it does not appear to be the remnants of a persistent channel in the cartilage which has not obliterated during the fusion of the ossification centers From the observation made from the histologic studies this appears to be a channel formed during osteogenesis when vessels are uniting with the marrow spaces by erupting from the periosteum into the dissolving cartilage and the newly developing bone BATSON (1942) and AREY (1950) have stressed that the vessels of the craniopharyngeal area and the basisphenoid are situated *in portions of the skull that are in line with the vertebrae and that the vertebral* bodies are pierced dorsoventrally by vessels that simulate similar vessels Reference to the basi vertebral veins has been made by previous anatomists and reemphasized by BATSON (1942) and WAGONER & PENDERGRASS (1939) The vessels which occur in the craniopharyngeal area are contained in the paleocranium that is situated in line with the vertebrae The vessels in these areas may therefore not only be comparable they may even be *homologues*

Speculation as to why the canal appears and persists apparently depends on the factors which control the appearance, the location and the persistence of nutrient foramina and channels with bones.

Conclusion

The craniopharyngeal canal is an anatomic finding in the mammalian skull, found with decreasing incidence as one ascends the phylogenetic scale. In the majority of mammals the craniopharyngeal canal closes soon after birth. The passage however may persist throughout life in some species. Although patent and complete canals are rarely found, our studies indicate that the canal can usually not be demonstrated utilizing routine and special radiographic techniques. Even when patent canals are present in the disarticulated skull, this structure was not adequately demonstrated. The inability to show this conduit is probably due to the small size of the canal, the aeration of the sphenoid in the adult bone, and the difficulties in positioning the skull for radiographic demonstration of this structure in the base view.

A thin obliquely vertical line of reduced density traversing the midportion of the sphenoid was encountered in the lateral view studies of newborn skulls. Corresponding to the channels shown in the sagittal histologic sections, this was considered to represent the craniopharyngeal canal. This line or segments of such a line were roentgenologically demonstrated in 4 cases out of 400 skull films studied. The unaerated character of the newborn sphenoid probably accounts for the roentgenographic demonstration of the canal or segments of this structure. In 2 of these cases the vertical line did not completely traverse the body of the sphenoid.

In various species of animals despite the known presence of the canal, our studies indicated that the structure could not be shown in the lateral projection in specially prepared specimens.

The canal is not to be confused with the normal neonatal synchondroses occurring in the sphenoid bone. Histologic studies of the sphenoid bone of various premature and term stillborn fetuses showed no squamous cell arrest or cystic glandular structures suggestive of hypophyseal duct origin in the sphenoid bone. The histologic studies made of sagittal sections of the sphenoid bone in cats and rabbits demonstrated persistent craniopharyngeal canals. Vascular structures in the canal were demonstrated in these sections. One animal demonstrated connective tissue lined by cuboidal epithelium similar to that of the median lobe of the pituitary. Myelinated nerve fibers were not seen in either animal species. Although various theories exist concerning the anatomic and embryologic significance of the craniopharyngeal canal, our

studies indicate that this probably represents the residuum of the canal formed during osteogenesis when vessels are connecting and are being distributed through the marrow spaces by erupting from the periosteum into the fetal cartilage and the adjacent developing spongy bone The mechanism of the development of this canal is much the same as the formation of the channels occupied by the basivertebral vein in the body of a vertebra This conduit for vessels and nerves has been previously interpreted in the past as the path way of the former stalk of Rathke s pouch While the hypophyseal stalk is obliterated early, the later appearing craniopharyngeal canal pursues the same general direction Since the present designations describing this structure imply a neurogenic embryonic origin derivation these should be discarded More appropriate, would seem to be the use of the term intrasphenoidal channel

Acknowledgement

This study was supported by the James Hudson Fund Yale University School of Medicine

SUMMARY

The craniopharyngeal canal is an anatomic finding in the mammalian skull *found with* decreasing incidence as one ascends the phylo enetic scale The channel is rarely encountered in human infancy This channel for vessels and nerves previously considered the conduit for the former stalk of Rathke s pouch is rarely demonstrated roentgenographically The canal when it persists is *apparently formed* during embryologic osteogenesis and vascularization of the body of the sphenoid bone

ZUSAMMENFASSUNG

D r Craniopharyngealkanal wird normaler*weise am* Mammalia Schadel gefunden Er kommt jedoch in abnehmender Frequenz vor je hoher die phylogenetische Entwicklung ist Beim menschlichen Kinde findet man ihn *selten* Der Kanal fur Gefasse und Nerven und ursprunglich fur den Stiel der Rathkesch*en Tas he* vorgesehen ist rontgenologisch selten darstellbar Beim Fersistieren des Kanals wird er offensichtlich wahrend der embryonalen Osteogenese und Vaskularisierung des Keilbein*korpers gebildet*

RÉSUMÉ

On trouve d autant moins *fréquemment le canal* craniopharyngien dans le crane des mammifères qu on s élève dans l échelle phylogénique Ce canal existe rarement chez le nourris*son humain* Ce canal destiné a des vaisseaux et à des n rfs et considéré autrefois comme destiné à la tige de la poche de Rathke est *rarement mis* en évidence radiographiquement *Quand il* persiste il parait formé au cours de l ostéogénese et de la vascularisation *embryolo*g ques du corps de l os sphénoide

REFERENCES

ARAI H Der Inhalt des Canalis cranio pharyngeus Anat Hefte 33 (1907) 411

AREY L B The craniopharyngeal canal reviewed and reinterpreted Anat Rec 106 (1950) 1

BATSON O V Vertebral veins in metastatic processes Ann intern Med 16 (1942) 38

— Vertebral vein system as a mechanism for the spread of metastases Amer J Roentgenol 48 (1942) 715

CAFFEY J Pediatric x ray diagnosis Year Book Publishers, Chicago 1950

CAVE A J E *The craniopharyngeal canal in man and mammal J Anat 64 (1941) 363*

CITELLI I Sur la frequence relative du canal cranio pharyngien chez les enfants et les jeunes gens et sur l importance de ce fait pour ma theorie Ann Mal Oreil Larynx 39 (1913) 338

DRAGER C A Nerve fibers within the craniopharyngeal canal Anat Rec 88 (1944) 235

DYKE C G Persistent craniopharyngeal canal in diagnostic roentgenology Ed by R Golden p *30F* Williams & Wilkins Co Baltimore *1948*

GARSCHIN W Ein Fall der intrasphenoidalen Hypophysengangsgeschwulst *Z* Krebforsch 31 (1930) 432

HABERFELD W Die Rachendachhypophyse andere Hypophysengangreste und deren Bedeutung fur die Pathologie Beitr path Anat 46 (1909) 133

HENLE J Handbuch der systematischen ana Anatomie des Menschen Vieweg und sohn Branschweig 1 part 1 (1855) 283

KOHLER A and ZIMMER E A Borderlands of the normal and early pathologic in skeletal roentgenology Grune & Stratton Inc New York 1956

LANDZERT T Ueber den Canalis craniopharyngeus am Schadel des Neugeborenen St Peters med Ztschr 14 (1868) 133

MAGGI L Intorno al canale cranio faringeo in alcuni rosicanti Reale Ist Lombardo di sci e lett (Rendiconti) Ser 2 23 (1890) 729

MALL F P On ossification centers in human embryos less than 100 days old Amer J Anat 5 (1896) 433

RATHKE H Nachtragliche Bemerkungen zu dem Aufsatze uber die Entstehung der Glandula pituitaria Arch f Anat Physiol und wissenschaftliche Medizin von Muller 1839

SHAPIRO R and JANZEN A H The normal skull a roentgen study Paul B Hoeber Inc New York 1960

SOKOLOW P Der Canalis craniopharyngeus Arch f Anat u Physiol Anat Abth (1904) 71

TILNEY F Bull neurol Inst N Y 5 (1936) 387

VIRCHOW R Untersuchungen uber die Entwicklung des Schadelgrundes etc Reimer Berlin 1857

WAGONER G and PENDLERGRASS E P The anterior and posterior notch shadows seen in lateral roentgenograms of the vertebra in infants Amer J Roentgenol 42 (1939) 663

OBSERVATIONS ON CRANIOLACUNIA

by

DONALD L MCRAE

Craniolacunia also called lacunar skull or Luckenschadel is sometimes considered a cranial dysplasia of no practical importance However, long term follow up of patients born with this condition shows it to be of importance in prognosis Patients with craniolacunia have high morbidity and mortality due to associated lesions of the central nervous system and to the secondary effects of the neurological lesions (VOGT & WYATT 1941) Craniolacunia is frequently associated with myelomeningocele and encephalocele less often with simple meningocele Patients with craniolacunia frequently develop hydrocephalus due to stenosis of the aqueduct of Sylvius and/or to the Arnold Chiari malformation They are frequently found to have paraplegia deformities of the legs and feet, and urinary and fecal incontinence

Craniolacunia is characterized by groups of round oval or finger shaped pits in the inner surface of the cranial vault, separated by slender ridges of bone (Fig 1a)

The deepest pits may penetrate the full thickness of the vault and become palpable The pits and ridges are most obvious in the thickest parts of the frontal parietal and occipital portions of the vault The newer and thinner portions of these bones are less often and less markedly involved In the occipital squama the lesions tend to be concentrated just above the internal occipital protuberance with their long axes in a parasagittal direction and the deepest



Fig. 1. Male aged 20 days, born with a lumbo-sacral myelomeningocele. Lacunae + + + are seen in (a).



Fig. 2. Female aged 2 1/4 months, admitted because of an enlarging head; no meningocele of any type could be found. Ventriculography disclosed stenosis of the aqueduct of Sylvius and a ventriculoatrial shunt (Torkildsen procedure) was carried out. The head continued to enlarge but at a slower rate. She is reported to have died at home in her second year, cause unknown. Lacunae + +.

part of the pit lying against the attachment of the tentorium (Fig. 1b). The lacunae are present for a few months in fetal and postnatal life, run a predetermined course and then disappear, never to re-appear.

Skull and spine films of all patients indexed as craniolacunia, encephalocele, myelomeningocele and meningocele were reviewed. Sixty-nine cases of craniolacunia were found. Fifty-eight infants with encephalocele, myelomeningocele or meningocele had undoubted craniolacunia. Ten others showed probable



Fig 3 Female aged 1 month born with a small head and a large occipital encephalocele The sac and its contents were excised but the baby died a few hours after operation Lacunae+++ Gas has been injected into the sac to see if communication between the sac and the cranium could be established

craniolacunia The latter were all less than 3 months of age and had lacunae or impressions on the thickest parts of the frontal parietal and occipital bones with intervening normal bone One infant 2 1/2 months old with hydrocephalus but without an encephalocele or meningocele had undoubted craniolacunia (Fig 2)

There were 17 patients with encephaloceles 2 with cranial meningoceles 8 with spinal meningoceles 41 with spinal myelomeningoceles and 1 who had hydrocephalus without meningocele There were 37 females and 32 males

The lacunar markings on the skull were scored on a scale of four ++++ = lacunae deep sharp edged and numerous involving all parts of the vault +++ = lacunae deep sharp-edged, but involving only the thickest parts of the frontal parietal and occipital bones ++ = definite lacunae but with bevelled edges + = lacunae more or less resembling convolutional markings but present only in the thick parts of the frontal parietal and occipital bones with intervening normal bone and present within the first 3 months of life

For purposes of further analysis the 4+ and 3+ cases were grouped as marked craniolacunia the 2+ cases as moderate and 1+ as slight



Fig. 4. Male aged 4 days. Lacunae++++. The occipital encephalocele was excised. No signs of increased intracranial pressure.

The essential cause of the lacunae is not exactly known. The lacunae are on the inner surface of the vault and do not seem to occur in the base. Since the bones of the base are of endochondral origin, it seems that craniolacunia is a dysplasia of bone of intramembranous origin. The frequent occurrence of craniolacunia in the upper half of the occipital squama (the intramembranous part) and their almost complete absence in the lower half of the occipital squama (the endochrondral part) supports this hypothesis. At post mortem, one finds thickened dural bands over the bony ridges. The dura is thinner in the lacunae than elsewhere but it is not clear whether this is a primary or a secondary thinning of the dura.

There are several reasons for doubting that the lacunae represent convolutional impressions. Craniolacunia is found in infants with low intracranial pressure (Fig. 3).

Five of the 69 children in this series had low intracranial pressure as shown by an abnormally small skull with open sutures. In all five this was due to the presence of a large encephalocele. Four of these children had marked craniolacunia and one had lacunae of moderate degree. Craniolacunia is found in infants who have no sign of increased intracranial pressure before or after birth (Fig. 4). Craniolacunia is found in fetal life and early infancy before brain markings are expected. Occasionally in normal new born infants a few faint brain markings are seen on the top of the vault, probably due to the head down position in utero. However, brain markings usually do not appear in normal children until 1 or 2 years of age and then are most obvious on the



Fig 5 Female aged 10 days born with a lumbosacral myelomeningocele and paraplegia Lacunae ++

lower and posterior parts of the cranial vault as well as on the base These are not the common areas for lacunar markings In hydrocephalic infants brain markings are rare before 3 months of age and when they occur they are usually generalized In children with premature synostosis of the cranial sutures brain markings are rare before the age of 2 months and when present are most marked where the brain is pushing hardest on the bone

Diagnostic criteria of the condition The age at which the lacunae appear and disappear is not known accurately for several reasons The lacunae begin to appear when the infant is in utero where the skull is not readily examined I suspect that in some infants it appears soon after the cranial vault begins to ossify i e soon after the eighth week of fetal life I have seen marked craniolacunia in infants in utero at an estimated age of 7 1/2 months It has been reported as early as 8 months (HARTLEY & BURNETT 1943, MAIER 1934) Since the depth and number of the lacunae vary from case to case the ease with which it can be recognized in roentgenograms of the mother s abdomen varies Radiography of the pregnant female is not often carried out in the second trimester of pregnancy and therefore we have no large series of cases for accurate estimation of the age at the appearance of the lesions or the evolution

The age at which the lesions disappear varies Some children are born with lesions already fading (Fig 5) Five slight cases were less than 1 month old It can be assumed that their lacunae were most marked in utero The other six



Fig. 6. Female born with a small sub-occipital meningocele and a Klippel-Feil deformity. Films at ages 1 week and 1 month show fading of the lacunae to resemble brain markings. No sign of increased intracranial pressure. At age 9 years her skull was normal in size and except for the Klippel-Feil deformity she was considered normal.



Fig. 7. Female born with a lumbar myelomeningocele and paraplegia. The head enlarged rapidly but was controlled by a shunt. At age 3 1/2 years she was paraplegic, incontinent and showed some mental retardation. Films at 3 days and 2 months.

slight cases were over 1 month of age. Their lacunae were probably most marked about the time of birth.

The lacunae seem to run a pre-determined course, a course not altered by low, normal or high intracranial pressure. In some cases the sharp edges of the lacunae became bevelled in a month or two so that they resembled brain markings (Fig. 6). Occasionally the lacunae became unrecognizable in this length of time (Fig. 7). In other cases there was little change in two or three



Fig 8 Female born with a lumbo sacral myelomeningocele very little movement of the legs saddle anesthesia and relaxed anal sphincter Skull films at 14 days and 4 1/2 weeks of age showing little change in spite of increased intracranial pressure

months (Fig 8) There were no definite lacunae after 6 months of age Some reported cases of craniolacunia in adolescents and young adults are actually examples of prominent brain markings

Any infant skull with impressions on the inner table of the vault before the age of 4 months should be considered as a possible case of craniolacunia, especially if the markings are high and anterior on the vault

Incidence of congenital anomalies The commonest anomalies associated with craniolacunia are myelomeningocele encephalocele and simple meningocele Only ten of the patients with craniolacunia had simple meningoceles while 58 had either encephaloceles or myelomeningoceles VOGT & WYATT (1941) gave the incidence of craniolacunia in patients with all types of meningoceles as 43 % They found craniolacunia in 12 % of simple meningoceles and in 53 % of myelomeningoceles

Twenty eight of the 49 cases in this series who had craniolacunia and spinal myelomeningocele or meningocele were paraplegic Some of the remaining 21 had a monoplegia and others in whom leg movements were present had sphincter paralysis with saddle anesthesia Fourteen had unilateral or bilateral club foot Anomalies of the ribs were common when the spinal lesion was in the thoracic region Eight patients in the total series showed the Klippel Feil deformity and all eight had encephaloceles myelomeningoceles or meningoceles Diastematomyelia was present in at least four and probably in more Miscellaneous abnormalities were dextrocardia inguinal hernia dislocated hips and squint



Fig 6 Female born with a small sub occipital meningocele and a Klippel Feil deformity Films at ages 1 week and 1 month show fading of the lacunae to resemble brain marking No sign of increased intracranial pressure At age 9 years her skull was normal in size and except for the Klippel Feil deformity she was considered normal



Fig 7 Female born with a lumbar myelomeningocele and paraplegia The head enlarged rapidly but was controlled by a shunt At age 3 1/2 years she was paraplegic incontinent and showed some mental retardation Films at 3 days and 2 months

slight cases were over 1 month of age Their lacunae were probably most marked about the time of birth

The lacunae seem to run a pre determined course, a course not altered by low, normal or high intracranial pressure In some cases the sharp edges of the lacunae became bevelled in a month or two so that they resembled brain markings (Fig 6) Occasionally the lacunae became unrecognizable in this length of time (Fig 7) In other cases there was little change in two or three



Fig 8 Female born with a lumbo sacral myelomeningocele very little movement of the legs saddle anesthesia and relaxed anal sphincter Skull films at 14 days and 4 1/2 weeks of age showing little change in spite of increased intracranial pressure

months (Fig 8) There were no definite lacunae after 6 months of age Some reported cases of craniolacunia in adolescents and young adults are actually examples of prominent brain markings

Any infant skull with impressions on the inner table of the vault before the age of 4 months should be considered as a possible case of craniolacunia especially if the markings are high and anterior on the vault

Incidence of congenital anomalies The commonest anomalies associated with craniolacunia are myelomeningocele encephalocele and simple meningocele Only ten of the patients with craniolacunia had simple meningoceles while 58 had either encephaloceles or myelomeningoceles VOGT & WYATT (1941) gave the incidence of craniolacunia in patients with all types of meningoceles as 43 % They found craniolacunia in 12 % of simple meningoceles and in 53 % of myelomeningoceles

Twenty eight of the 49 cases in this series who had craniolacunia and spinal myelomeningocele or meningocele were paraplegic Some of the remaining 21 had a monoplegia and others in whom leg movements were present had sphincter paralysis with saddle anesthesia Fourteen had unilateral or bilateral club foot Anomalies of the ribs were common when the spinal lesion was in the thoracic region Eight patients in the total series showed the Klippel Feil deformity and all eight had encephaloceles myelomeningoceles or meningoceles Diastematomyelia was present in at least four and probably in more Miscellaneous abnormalities were dextrocardia inguinal hernia dislocated hips and squint

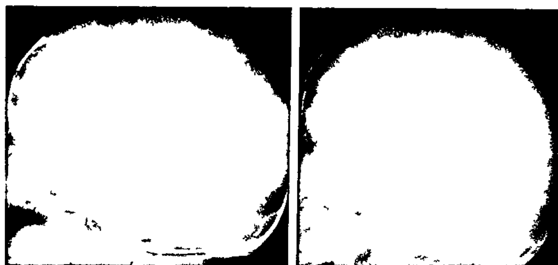


Fig 6 Female born with a small sub occipital meningocele and a Klippel Feil deformity Films at ages 1 week and 1 month show fading of the lacunae to resemble brain markings No sign of increased intracranial pressure At age 9 years her skull was normal in size and except for the Klippel Feil deformity she was considered normal



Fig 7 Female born with a lumbar myelomeningocele and paraplegia The head enlarged rapidly but was controlled by a shunt At age 3 1/2 years she was paraplegic incontinent and showed some mental retardation Films at 3 days and 2 months

slight cases were over 1 month of age Their lacunae were probably most marked about the time of birth

The lacunae seem to run a pre determined course a course not altered by low, normal or high intracranial pressure In some cases the sharp edges of the lacunae became bevelled in a month or two so that they resembled brain markings (Fig 6) Occasionally the lacunae became unrecognizable in this length of time (Fig 7) In other cases there was little change in two or three

Thirty two patients had a clearly visible synchondrosis between the pre sphenoid and post sphenoid portions of the sphenoid bone This is much more frequent than in normal new born children and may be evidence of immaturity of the part of the skull derived from cartilage

Prognosis Some of these patients came from distant provinces or other countries and some were treated here many years ago It was difficult to trace all the patients The approximate morbidity and mortality can be seen in the Table

Twenty three patients were alive two or more years after birth Nine were of normal intelligence and physically were fairly normal Included in this group were children with Klippel Feil deformity and also club feet Seven showed some degree of mental retardation usually with some other physical abnormality Seven were paraplegic but two of these were walking with bilateral leg braces and crutches Since the last visit of some of these patients was many years ago some may have died since from urinary tract infections or from hydrocephalus

Five are presumed to be alive since they were discharged from the hospital in infancy with no sign of hydrocephalus or paraplegia and have not returned

Ten patients are known to have died, mostly *in the first year of life One was the hydrocephalic* patient without meningocele who died at the age of *two* One was a retarded paraplegic who had a cord bladder and died of uremia at 8 years of age

Sixteen are presumed to be dead as they were discharged from the hospital *in infancy* without treatment In most cases this was because of a combination *of* rapidly developing hydrocephalus and a severe spinal lesion with para*plegia*

We were unable to trace 15 patients whose encephalocele *meningocele or myelomeningocele* was repaired satisfactorily and who had either paraplegia alone or hydrocephalus alone *which had been treated* by shunt operation They are listed as questionable

Conclusions

Congenital anomalies are frequent in these *patients*

The lacunar markings in the skull appear in fetal life in the membranous part of the cranial vault They are grouped *in the* thickest parts of the frontal parietal and upper occipital squamae The *lacunae* begin to fade around the time of birth and are usually unrecognizable by the age of 4 to 6 months They are not related to increased intracranial pressure, and were in fact marked in patients who had low intracranial pressure

Table

Prognosis in craniolacunia

Lacunae	Age at death	Presumed dead	?	Presumed alive	Age last visit
Encephalocele *17 cases*					
Marked 7 cases	1 month 14 days	Two	Two	One	0
Moderate 8 cases	2 months	One	Two	Two	17 yrs Normal except squint 14 yrs Klippel Feil I Q 56
Slight 2 cases	0	0	0	0	7 1/2 yrs Normal except Klippel Feil 11 yrs Normal
Meningocele *? cranial* *8 spinal*					
Marked 5 cases	0	Two	Two	0	5 yrs Klippel Feil I Q 90
Moderate 2 cases	0	0	0	0	11 yrs Normal except Klippel Feil 12 yrs Seizures moderate retardation
Slight 3 cases	0	0	0	0	16 yrs Normal 11 yrs Normal except club foot 7 yrs Normal
Myelomenin gocele *41 cases*					
Marked 21 cases	4 months 13 days 2 months	Nine	Four	One	3 1/2 yrs Large head normal intelligence 4 1/2 yrs Paraplegia slight retardation 3 yrs Paraplegia seizures 4 yrs Paraplegia large head
Moderate 13 cases	3 months 1 year	Two	Two	Two	5 yrs Large head normal intelligence 12 yrs Club foot I Q 72 2 yrs Paraplegia large head 16 yrs Paraplgiga I Q 63 3 1/2 yrs Paraplegia pyelonephritis 2 yrs Club foot large head 17 yrs Normal except club foot
Slight 7 cases	8 years	0	Three	One	7 yrs Paraplegia slightly retarded 9 yrs Normal except club foot
No meningo cele *1 case*					
Moderate	2 years	0	0	0	0
Totals	10	16	15	[illegible]	23

HOSPITAL T. ALVAREZ, BUENOS AIRES, ARGENTINA

RADIOLOGICAL LOCALIZATION OF THE PINEAL GLAND

by

MARCELO H. MOREAU

There are a number of methods for the determination of displacement of the pineal calcification. The method most generally used is the Vastine-Kinney or the Dyke modification which is of great value but presents certain difficulties in the way in which the occipital points are marked, particularly the inferior one.

To obviate this disadvantage we propose another method of localization based on a review of 250 cases. Using the lateral film of the skull we propose to relate the calcified pineal body to the *nasion sella turcica (middle center) plane*. We recommend that the film be perforated with a pin at the nasion in order to set a fixed point for measurement of this plane.

Then the occipital angle is determined. This is formed by the nasion sella turcica plane with another plane extending from the nasion to the inferior occipital point (see figure). The values of this angle are A 10, B-14, C 18, D 22, E 26.

Subsequently the *pineal angle* is obtained above the nasion sella turcica plane which arises from the center of the sella turcica. Values are A-42, B 38, C 34, D 30, E 26 (see figure).

A transparent film localizer is used which when placed upon the radio

Ten are known to have died and 16 are *presumed to be dead*, a *mortality* of 37 % of all patients and a mortality rate of approximately 50 % of all those in whom a reasonable judgment of the outcome could be made. Twenty-three are known to be alive and 5 are presumed to be alive, a survival rate of approximately 40 % of all cases or approximately 50 % of all cases in whom a reasonable decision as to the outcome was possible. Of the 23 known to be alive, 11 are normal or fairly normal.

All children born with spinal anomalies should have skull films made. If craniolacunia is shown, the chance of the child having severe and/or multiple lesions of the central nervous system is great.

SUMMARY

Sixty-nine patients with craniolacunia are reported. Multiple, often severe, lesions of the central nervous system are frequent in this series.

ZUSAMMENFASSUNG

Es wird uber 69 Patienten mit Craniolakunen berichtet. In dieser Serie sind häufig multiple, oft ernste Schäden des ZNS vorhanden.

RÉSUMÉ

Présentation de 69 cas de crâne lacunaire. Les lésions multiples, souvent graves, du système nerveux central sont fréquentes dans cette série.

REFERENCES

HARTLEY, J. B. and BURNETT, C. W. F. The radiological diagnosis of craniolacunia. Brit. J. Radiol. 16 (1943) 99.

MAIER, R. J. Prenatal diagnosis of lacunar skull. Radiology 23 (1934) 615.

VOGT, E. C. and WYATT, G. M. Craniolacunia (Luckenschadel). Radiology 36 (1941) 147.

We believe that this method of localization has an accuracy which is probably similar to that of the Vastine Kinney Dyke method

From our experience it appears that the greater the pineal angle the smaller is the occipital angle and vice versa

SUMMARY

The author proposes to determine the position of the calcified pineal gland in lateral roentgenograms of the skull by its relationship with the nasion sella turcica (middle center) plane The occipital angle is determined as well as the corresponding pineal angle This indicates roughly the position of the pineal gland The sella skull diameter divided by 2 6 indicates the position of the gland more accurately

ZUSAMMENFASSUNG

Der Verfasser schlagt vor auf Seitenaufnahmen des Schadels die Lage der verkalkten Zirbeldruse unter Bezugnahme auf die Nasion Sella Linie zu bestimmen Der Occipital winkel und der entsprechende Pinealwinkel werden gemessen Diese bestimmen annahernd die Lage des Pinealkorpers die dann mit grosserer Genauigkeit festgelegt wird indem man den Abstand von der Sella zum Schadel durch 2 6 teilt

RÉSUMÉ

L auteur s est efforcé de déterminer la position de l épiphyse sur les radiographies de profil du crâne par rapport au plan nasion selle turcique Il a mesuré l angle occipital ainsi que l angle pinéal correspondant sur lequel ou près duquel doit se trouver la glande pinéale Le diamètre selle turcique voute divisé par 2 6 indique la position de la glande

REFERENCES

DYKE C C Indirect signs of brain tumors as noted in routine roentgen examinations displacement of pineal shadow Amer J Roentgenol 23 (1930) 598

EPSTEIN B and DAVIDOFF L An atlas of skull roentgenograms Lea and Febiger Philadelphia 1953

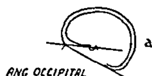
FRAY N W A roentgenological study of pineal orientation A comparison of methods used in pineal orientation Amer J Roentgenol 39 (1938) 899

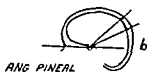
GEFFEN A A new ruler graph for localization of the pineal body Amer J Roentgenol 73 (1955) 118

PANCOAST H PENDERGRASS E and SCHAEFFER P The head and neck in roentgen diagnosis Charles C Thomas Springfield Ill 1940

VASTINE J H and KINNEY K K Pineal shadow as aid in localization of brain tumours Amer J Roentgenol 17 (1927) 320

Sella Vault	Sella Pineal
16 cm	62 mm
15 5	60
15	58
14 5	56
14	54
13 5	52
13	50
12 5	48
12	46
11 5	44
11	42
10 5	40
10	38
9 5	36
9	34





	ANG OCC	ANG PINEAL
A	10	42
B	14	38
C	18	34
D	22	30
E	26	26

The figure is drawn on a transparent film When superposed upon the radiographic film as indicated in *a* and *b* the occipital angle pineal angle and the ideal position of the pineal gland may be determined

graphic film as indicated in *a*, allows measurement of the occipital angle (A, B, C, D or E) Then the localizer is moved as shown in *b* of the figure and observe the *pineal angle* (A, B, C, D, or E), in the same letter of the occipital angle which has previously been measured The lines representing the various angles of the pineal angle are marked in centimeters (see figure)

The pineal usually falls over one or near one of the lines of the various angles or it may be as much as 7 mm forward and up or 7 mm back and down

The pineal distance to the center of the sella turcica is obtained by dividing (on the pineal angle line) the distance from the center of the sella to the middle of the vault by 2 6 (see b in the figure) The distance of the pineal is indicated in the upper left corner of the pineal localizer, the varying sella turcica pineal distance in relation to the variation in sella turcica vault diameter can be readily appreciated These distances are plus or minus 5 mm



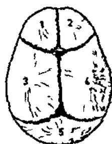


Fig 1 Basic buttresses and situation of the ossification centers of the vault of the skull

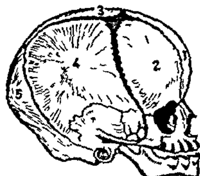


Fig 2 Situation of the sutures following the main direction of the basic buttresses

2 between the falx and the continuation of the sphenoid wings and pyramids both the *parietal* points,

3 between the pyramids behind the *single occipital* point

The ossification of the vault proceeds with the continued growth of the brain The bone beams extend along the vascular pattern until the borders of bone centers come into contact with each other There the sutures are formed The sutures are consequently situated in the continuation of the above named buttresses (Fig 2)

We are now able to make the correlation of these observations in normal development by radiological investigations of skulls with a disturbed *develop* ment the so called oxycephalics

Exact data for the vault and base deformity have been gained from various lines and angles obtained from 20 roentgenograms of patients afflicted with such an anomaly Data of 200 normal skulls have been compared with these The characteristic deformity *of the vault known* since the days of HIPPOCRATES (in German referred to as *Turmschadel*) must be combined after the findings of VIRCHOW with a severe deformity of the base

In the axial projection which offers the best *view of the base*, a typical deviation from the normal proportions is evident The sphenoid wings form a greater angle than normal *The axes remain* in a more transverse direction The exact measurements of these angles are sphenoid angle, normal 90 sphenoid angle in oxycephaly 120 The statistical significance is very high with a *t* of 16 (Figs 3 and 4)

With increase of the sphenoid angle the axis of the eyes also changes The

AUS MED. STRAHLENINSTITUT (DIRECTOR: PROF. R. BAUER) DER UNIVERSITÄT, TÜBINGEN, WEST GERMANY

MAIN PRINCIPLES IN DISTURBED DEVELOPMENT OF THE SKULL

Radiological observations

by

HERMANN SCHMIDT

Connections between the base and the vault of the skull in disturbed development have been known since the time of VIRCHOW (1857). This author stated that there is 'no deformity of the vault without deformity of the base'. Later investigations independent of VIRCHOW's observations, and made by anatomists, have made these connections more evident.

During embryonal development the ossification of the skull begins early in the third month. The first centers appear in the base. The vault is stretched over the brain. When the pressure of the growing brain has reached a certain degree the ossification of the vault begins. The first ossification centers appear at the points of highest growth pressure.

The base as the foundation of the brain also forms the transverse buttresses for the vault of the skull. The main transverse buttresses are the pyramids and the sphenoid wings, the sagittal buttress is the falx cerebri. These buttresses bear the growth pressure of the brain, between them, however, must be the highest scale of pressure. Therefore the first five centers of ossification arise (Fig. 1):

1. between the falx and the continuation of the sphenoid wings: both the *frontal* points,



Fig 5 Oxycephaly Short frontal and parietal bone



Fig 6 Situation of the ossification centers in oxycephaly (after RIEPING)



Fig. 3 Sphenoid angle in a normal adult

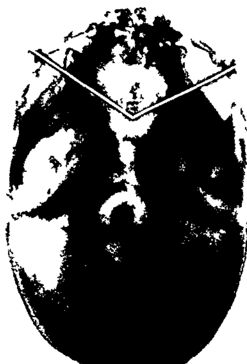


Fig. 4 Sphenoid angle in oxycephaly

view axes are turned aside. GREIG says in his description of hypertelorism 'He looks like a hare.' As a result we have a divergent strabism.

Understandably, the hypertelorism — that is the increased distance between the eyes — depends on this lateral movement of the sphenoid wings. The ethmoid cells become enlarged.

The cranial changes in oxycephaly are well known. Apart from the tower like deformity there is lack of bulging and shortening of the frontal bone, and as a rule the coronal suture is closed (Fig. 5). Measurements prove that in oxycephaly there is regularly not only a short frontal, but also a short parietal bone. The sphenoid angle is normally 95, in oxycephaly 115, the angle Endobregma Tuberculum sellae Endolambda is normally 69—17.6 FE—, in oxycephaly 56—15.8 FE (FE = Flächeneinheit).

The lateral displacement of the sphenoid wings, as the buttresses for the vault in the skull development, is combined with the shortening of the frontal and parietal bone and the closed coronal suture.

The architecture of bones and the localization of the bone centers may be observed in childhood. In oxycephaly the frontal and parietal centers are situated extremely close to each other so close that both centers may have

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY VICTORIA HOSPITAL LONDON
ONTARIO CANADA

ARTERIAL SPASM IN SUBARACHNOID HAEMORRHAGE

A clinical and experimental study

by

J M Allcock

The records of all patients admitted to Victoria Hospital since 1952 with a diagnosis of subarachnoid haemorrhage have recently been studied and the facts and conclusions obtained from this survey have been given in two papers (Allcock & Drake 1963 and in publication)

The first of these showed the necessity of postoperative angiography as a routine procedure Without angiography one knows little as to the cause of variations in the clinical state and it is impossible to assess honestly the effectiveness of different surgical techniques It was found for instance that in some patients in whom the surgeon had felt confident at the time of operation that the sac had been completely obliterated there was in fact a significant portion of the aneurysm still filling with contrast In others a major vessel had been occluded Many of these patients were doing well and without the post operative angiography would have been recorded as surgical successes

However the major conclusion was that arterial spasm was one of the main causes of post operative morbidity and mortality The second study was undertaken to find any factors that might be causing this spasm

There were 195 patients in whom the source of a subarachnoid haemorrhage

been united from their inception. Only GREIG has observed this peculiarity in adults and has described it as the pterio-stephanic ankylosis in oxycephaly.

The connection with the base deformity is now understandable. If the sphenoid wings stay too far apart from each other, one must expect an approach of the frontal and parietal centers as a result of the forementioned dependence of situation between the buttresses of the base and the ossification centers. This is the reason for the premature closure of the coronal suture. It is a consequence of, not the reason for, oxycephaly.

We have named the characteristic base deformity 'frontal dysplasia', because it concerns the frontal groove and above all the frontal bone. There are still other signs of frontal dysplasia which will not be mentioned here.

Frontal dysplasia and oxycephaly are dependent on each other. With this interpretation the disturbed development fits the anatomic observations of the skull, and also VIRCHOW's statement 'no deformity of vault without deformity of base'.

SUMMARY

Measurements from roentgenograms in 20 cases of oxycephaly, compared with the same *measurements in 100 normal cases, are presented. The typical appearances of the vault in* oxycephaly depend on the primary deformity of the base of the skull.

ZUSAMMENFASSUNG

Röntgenbild-Schädelmessungen bei 20 Fällen von Oxycephalie werden mit denen von 100 Normalfällen verglichen. Das typische Aussehen der Kalotte bei Oxycephalie hängt von der primären Deformität der Schädelbasis ab.

RÉSUMÉ

Présentation de mesures faites sur des radiographies dans 20 cas d'oxycéphalie comparées aux mêmes mesures dans 100 cas normaux. L'aspect typique de la voûte du crâne dans l'oxycéphalie dépend de la déformation primitive de la base du crâne.

REFERENCES

GREIG, D. M.: Oxycephaly. Edinb. med. J. 33 (1926), 189, 280, 357.

RIEPING, A.: Zur Pathogenese des Turmschädels. Dtsch. Z. Chir. 148 (1910), 1.

VIRCHOW, R.: Untersuchungen über die Entwicklung des Schädelgrundes. Reimer, Berlin 1857.



Fig 3 a) Control film b) Narrowing of left internal and external carotid arteries and branches 1 min after injection of serotonin on left c) Normal appearances 8 min later

was shown by angiography to be a ruptured aneurysm, of whom 143 underwent surgery Post operative angiography was carried out in 92 of these and 38 or 41 % demonstrated evidence of arterial spasm

One factor that seemed to predispose to this was early operation In those showing post operative spasm the average period between the last haemorrhage and surgery was 5 4 days compared with 11 1 days in those who did not

Both hypothermia and hyperventilation during surgery had a bad influence Without cooling 27 % showed spasm later while in the group on whom hypothermia was used this figure rose to 50 % With normal ventilation the incidence of spasm was 35 % and in the patients who were hyperventilated the proportion showing spasm climbed to 67 % If both were used, spasm was seen later in 86 %

Artificial hypotension during the operation was of benefit This was employed in 20 cases and only 2 of these or 10 %, showed any evidence of spasm after surgery

The site of the aneurysm seemed to be of importance Operation on those arising from the carotid siphon was the most likely to provoke spasm and treatment of those on the middle cerebral artery seemed the least dangerous in this respect Other factors such as age sex pre operative state number of haemorrhages etc details of which were given in the second paper, were considered but they appeared to have no influence on the development of spasm



a b

Fig. 1. a) Pre-operative angiogram: aneurysm on posterior communicating artery; no spasm. b) Post-operative angiogram: aneurysm occluded; intense spasm of distal carotid syphon and of inferior part of pericallosal and middle cerebral arteries.



a b

Fig. 2. a) Normal anatomy of cranial arteries of dog showing common, internal and external carotid and anterior and middle cerebral arteries. b) Line drawing of right carotid system.



Fig 3 a) Control film b) Narrowing of left internal and external carotid arteries and branches 1 min after injection of serotonin on left c) Normal appearances 8 min later

was shown by angiography to be a ruptured aneurysm, of whom 143 underwent surgery Post operative angiography was carried out in 92 of these and 38 or 41 % demonstrated evidence of arterial spasm

One factor that seemed to predispose to this was early operation In those showing post operative spasm the average period between the last haemorrhage and surgery was 5 4 days compared with 11 1 days in those who did not

Both hypothermia and hyperventilation during surgery had a bad influence Without cooling 27 % showed spasm later while in the group on whom hypothermia was used this figure rose to 50 % With normal ventilation the incidence of spasm was 35 % and in the patients who were hyperventilated the proportion showing spasm climbed to 67 % If both were used spasm was seen later in 86 %

Artificial hypotension during the operation was of benefit This was employed in 20 cases and only 2 of these or 10 % showed any evidence of spasm after surgery

The site of the aneurysm seemed to be of importance Operation on those arising from the carotid siphon was the most likely to provoke spasm and treatment of those on the middle cerebral artery seemed the least dangerous in this respect Other factors such as age sex pre operative state number of haemorrhages etc details of which were given in the second paper were considered but they appeared to have no influence on the development of spasm

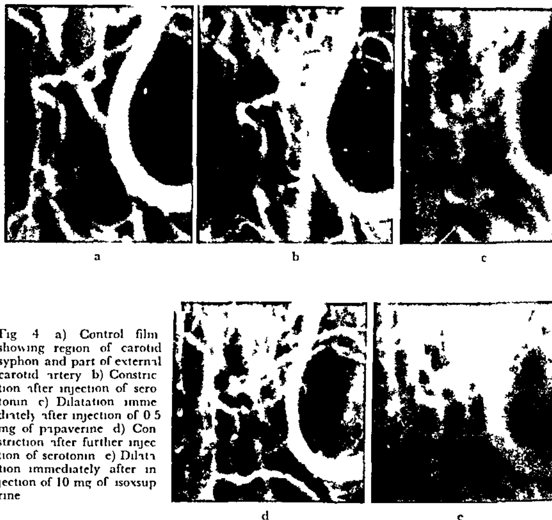


Fig 4 a) Control film showing region of carotid syphon and part of external carotid artery b) Constriction after injection of serotonin c) Dilatation immediately after injection of 0 5 mg of papaverine d) Constriction after further injection of serotonin e) Dilatation immediately after injection of 10 mg of isoxsuprine

There are many variables, so that it is hard to be sure that the figures quoted are of statistical significance However it is felt that they are of importance for the following reason Of those that showed post operative spasm only 46 % made a satisfactory recovery, without spasm the favourable outcome arose to 86 %

First of all, the cause of the appearance of the vessels in the angiogram shown in Fig 1b should be determined There are skeptics who think that the narrowing shown is due to axial flow rather than to spasm However, the blood in the vessels involved is in places flowing up vertically or around bends, and the arteries branch Such circumstances would tend to break up any effect due to axial flow The irregular segmental distribution of the spasm that is often seen would also be against this theory



Fig 5 a) Control film b) Constriction 1 min after injection of 1 mg of reserpine into artery

Others (e g TAVERAS 1963) have suggested that spasm occurs but that it is due to the contrast acting perhaps on an already irritable vessel There are several points against this theory It is not seen in other clinical states even when conditions favourable to the development of spasm might be thought to exist such as after operation on a vascular tumour When spasm is present the contrast appears to be dammed back so that the same part of an artery is filled with contrast medium at a later stage than usual in a series of films This suggests that the vessels were narrowed before the contrast ever reached them Post operative spasm has been shown to be associated nearly always with clinical signs appropriate to the vessel or vessels involved (ALLCOCK & DRAKE in publication)

Another possibility is that it may be due to the external pressure of a haematoma but the appearances sometimes seen with a large tumour or with cerebral oedema are quite different

It seems reasonable therefore to accept that arterial spasm exists that it is not due to the contrast medium that it appears to be associated exclusively with subarachnoid haemorrhage and that it has a bad influence on the prognosis

Clinically this problem has been approached here by delaying operation for 7 to 10 days after a haemorrhage unless recurrent haemorrhage or a



Fig 6 a) Control film b) No constriction after intra arterial injection of 1 mg of reserpine following treatment of dog with reserpine for 3 days c) Constriction still occurs after injection of serotonin

large haematoma make surgery imperative During this time the patient is kept hypotensive to minimize the risk of further bleeding At operation hypothermia and hyperventilation are avoided and the blood pressure is lowered still further Angiography is carried out in the operating room to check on the obliteration of the sac and to see if spasm is present After operation the blood pressure is raised to above normal with the hope of reducing the effect of any spasm if it develops, and this can be done safely with the knowledge that the sac is completely occluded Alcohol is given in large doses if there is any suggestion of clinical spasm (HEWER 1963)

Since this regime was adopted, 30 patients have been seen with ruptured aneurysms Three died awaiting operation One of these was comatose, the other two would have been considered candidates for surgery Seven either refused operation or were rejected for other reasons Of the 20 that were operated on, 15 had post operative angiography Only 2 of these, or 13 %, showed evidence of spasm compared with 41 % in the whole series In both of these the constriction was only seen in the immediate angiograms and not in those done a week later Only one patient who was operated on did badly, and at no time did she show any spasm

It seems therefore that a small part of the problem has been solved by avoiding the factors mentioned and by more energetic post operative treatment if spasm does occur However, it seems probable that these are merely precipitating agents and there is still some unknown underlying cause to be found One that has been suggested (RAYNOR et coll 1961) is the release of serotonin from blood in the cerebro spinal fluid or from damaged brain

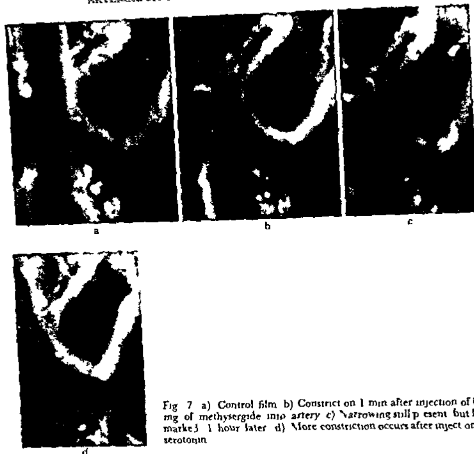


Fig 7 a) Control film b) Constriction 1 min after injection of 0 5 mg of methysergide into artery c) Narrowing still present but less marked 1 hour later d) More constriction occurs after injection of serotonin

With a view to studying these problems further a series of experiments on dogs has been undertaken These involve the injection of contrast material usually 3 to 5 ml of Conray into one or both common carotid arteries and the size of the radiographic image is magnified approximately 5 times by using a 0 3 mm focal spot with a short anode-object and a long anode film distance

Fig 2 shows the normal anatomy which is somewhat confusing owing to the large and numerous branches of the external carotid artery It is necessary to concentrate on a few of the larger arteries such as the internal carotid and anterior and middle cerebral vessels On occasion there would be good contrast filling of the vertebro-basilar tree through the posterior communicating arteries and when only one side was injected there was usually filling of the arteries on the opposite side through the anterior communicating artery and other collateral channels

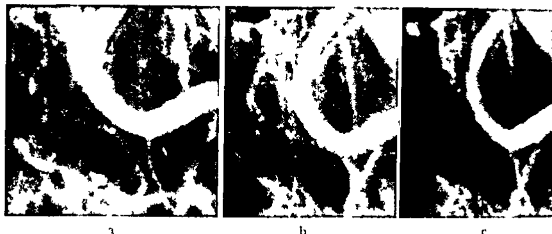


Fig 8 a) Control film b) Constriction present 1 hour after intravenous injection of 1 mg of methysergide c) Further constriction after injection of serotonin

The effect of injection into the artery of small doses of serotonin was first tried Fig 3a shows a control angiogram In Fig 3b there is narrowing of the left internal and external carotid arteries and their branches one minute after the injection of 2 micrograms of serotonin on that side Little if any change is seen on the right side, showing that the effect is local in nature Fig 3c shows that the left side has returned to normal 8 minutes after the injection of serotonin

A control film is shown in Fig 4a, while in Fig 4b the artery has been constricted by the injection of serotonin Immediately after this, 0 5 mg of papaverine was injected into the artery, and this reversed the spasm and in fact dilated the vessels to well above their original calibre (Fig 4c) The markedly increased blood flow was demonstrated by the fact that the amount of contrast used had to be increased from 5 to 20 ml and even then the degree of filling of the arteries was not as good as previously Narrowing occurred again (Fig 4d) after a further dose of serotonin Isoxsurpine, 10 mg (KARLSBERG et coll 1963) was then injected into the artery, producing an effect similar to that after the administration of papaverine (Fig 4e)

It has already been stated that in the pre operative period an attempt is made to keep the patient's blood pressure below normal Reserpine has been considered as the hypotensive agent

One effect of reserpine is to mobilize rapidly serotonin which has been stored in the cells After a control film, injection into the artery of 1 mg of reserpine causes appreciable narrowing of the vessels one minute later (Fig 5) This may be due to the local release of serotonin although the author has not been able to prove it as yet



Fig 9 a) Control film b) Marked constriction of distal carotid syphon and of anterior and middle cerebral arteries following hyperventilation c) Dilatation of same vessels immediately after intra arterial injection of 0 5 mg of papaverine

Another dog was given 1 mg of reserpine intramuscularly every day for three days in order to deplete his stores of serotonin Injection now of reserpine into the artery no longer causes constriction (Fig 6b) This would tend to support the theory mentioned above and at least it shows that the solution itself causes no change in calibre An amount of 5 micrograms of serotonin was then injected into the artery and the vessel was found to be still capable of reacting to it by constriction (Fig 6c)

These experiments would suggest that reserpine was perhaps not the ideal drug to use clinically under these circumstances as the initial release of serotonin might be just enough to precipitate spasm in a patient

Methysergide is a derivative of lysergic acid and a direct antagonist of serotonin in its action on smooth muscle This drug has been used in various experiments but so far the results have been disappointing After the injection of 1/2 mg of Sansert into the artery there is in fact some constriction (Fig 7b) and this effect is still present although less marked 1 hour later (Fig 7c) Injection of 5 micrograms of serotonin at this time causes some further narrowing (Fig 7d)

This contraction of the arteries is also seen after the intravenous administration of methysergide Fig 8 a and b show the appearances before and 1 hour after the injection of 1 mg of methysergide into a leg vein and in the second film there is definite constriction of the arteries Injection now of serotonin again causes some further narrowing (Fig 8c)

Hyperventilation is known to cause constriction of the cerebral vessels (KRUEGER et coll 1963) (cf Fig 9) The initial arterial blood pCO2 was 60 mm Hg and after hyperventilation and CO2 absorption this fell to 13 mm Hg In Fig 9b there is marked narrowing of the distal internal carotid and of the anterior and middle cerebral arteries and their branches The external carotid artery and its branches are hardly affected at all, as is found in humans This effect has been reversed, and the vessels are larger than initially, by the intra arterial injection of 0 5 mg of papaverine (Fig 9c) There is again the increased blood flow with accompanying lowered concentration of contrast in the artery, which has only in part been corrected by the use of an increased volume of contrast

The experiments that have been discussed are very incomplete and inconclusive, and it is recognized that much remains to be done before the ideas expressed have been proven correct or otherwise In the majority of cases the doses used were relatively large and the injections made rapidly, and the experiments are being repeated with slower administration of smaller doses

Most workers in this field have directed their attention towards the measurement of total cerebral blood flow or cerebro vascular resistance With the use of such methods it is hard to know where any changes are taking place It is felt that angiography offers a more direct and rational approach to the problem It shows the part of the arterial tree that is affected, and remains the only method by which clinical arterial spasm can be confirmed

Acknowledgements

The author is grateful to Sandoz Pharmaceuticals Dorval P Q for supplies of methysergide for administration by injection Ciba Ltd of Dorval P Q kindly supplied serpasil for use in these experiments

SUMMARY

Arterial spasm is a definite entity associated with subarachnoid haemorrhage and a potent source of post operative morbidity Its incidence can be reduced by delaying operation and by avoiding hypothermia and hyperventilation In this preliminary investigation reserpine appears unsuitable as a pre operative hypotensive agent and serotonin may be an underlying factor in the causation of clinical spasm Methysergide did not prevent the spasm induced by serotonin

ZUSAMMENFASSUNG

Arterieller Spasmus stellt ein einheitliches Bild bei Subarachnoidalblutung dar und kann die Ursache von postoperativen Komplikationen sein Diese Gefahr kann durch Aufschieben von operativen Eingriffen und Vermeidung von Hypothermie und Hyperventilation ver

mindert werden Aus dieser vorlaufigen Untersuchung geht hervor dass Reserpin als pra operatives Hypotonicum ungeeignet ist und Serotonin ein ursachlicher Faktor beim Auftreten von Spasmus sein kann Methysergid konnte den durch Serotonin ausgelosten Spasmus nicht verhindern

RÉSUME

Le spasme artériel est un état bien défini associé a l hémorragie sous arachnoidienne et une source importante de complications post-opérato res On peut réduire sa fréquence en retardant l opération et en évitant l hypothermie et l hyperventilation D après cette étude prél minaire la réserpine ne parait pas être un bon agent hypotenseur pré opératoire et la séroton ne peut être un facteur causal du spasme clinique La méthysergide n empeche pas le spasme dû a la sérotonine

REFERENCES

ALLCOCK J M and DRAKE C G Post operative angiography in cases of ruptured intracranial aneurysm J Neurosurg 20 (1963) 752

— — Ruptured intracranial aneurysms The role of arterial spasm J Neurosurg In publication

HEWER A J H Symposium on anaesthesia for neurosurgery Brit M J 2 (1963) 240

KARLSBERG I ELLIOT H W and ADAMS J E Effect of various pharmacologic agents on cerebral arteries Neurology 13 (1963) 772

KRUEGER T P ROCKOFF S D THOMAS L J and OMMAYA A K The effect of changes of end expiratory carbon dioxide on the normal cerebral angiogram Am J Roentgenol 90 (1963) 506

RAYNOR R B McMURTRY J G and POOL J L Cerebrovascular effects of topically applied serotonin in the cat Neurology 11 (1961) 190

TAVERAS J M Clinical Neurosurgery Williams & Wilkins Baltimore 1963 292

FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF J FRIMANN-DAHL), DEPARTMENT OF ANAESTHESIA (DIRECTOR DR I LUND), UNIVERSITY INSTITUTE FOR RESPIRATORY PHYSIOLOGY (DIRECTOR DR H ERIKSON), AND NEURORADIOLOGICAL DEPARTMENT (DIRECTOR DR I AMUNDSEN) ULLEVÅL HOSPITAL, OSLO, NORWAY

CIRCULATION TIME AND PATTERN IN CEREBRAL ANGIOGRAPHY USING DIFFERENT TECHNIQUES FOR GENERAL ANAESTHESIA

by

A K AMUNDSEN, P AMUNDSEN and H REFSUM

The carbon dioxide tension of the arterial blood is regarded as the most potent factor influencing the cerebral blood flow The normal limits for arterial pCO_2 are 35 to 45 mm of mercury An admixture of 5 to 7 % carbon dioxide to the inspired air will, in normal persons, bring the pCO_2 up to roughly 50, and this has been shown to influence the cerebral circulation significantly The blood flow, as determined for example by the nitrous oxide method, or by isotopes, increases and so does the circulation rate as determined during carotid angiography (SOKOLOFF 1959, KETY & SCHMIDT 1948, NOVAC et coll 1953, KRUEGER et coll 1963, TONNIS & SCHIEFER 1959 HARPER et coll 1964, LASSEN et coll 1963)

On the other hand it is a well known fact that actively conducted hyperventilation decreases cerebral blood flow and causes shrinkage of the brain, and it is therefore used as an effective method of reducing intracranial pressure during craniotomy



Fig 1 Carotid angiography a) Relaxant with controlled respiration pCO = 40 mm Hg b) Fluothane with spontaneous respiration pCO = 60 mm Hg



Fig 2 Left sided carotid angiography in same patient as in fig 1 14 days later a) Fluothane with spontaneous respiration b) Fluothane with hyperventilation slow circulation and marked cross circulation evident

Most drugs used for general anaesthesia tend to depress respiration and therefore may raise the carbon dioxide tension of the arterial blood During the anaesthetic this is counteracted by controlled respiration but during the period when spontaneous respiration is being resumed important changes in the carbon dioxide tension may be expected Up to the present little attention seems to have been paid to the extent to which these variations may occur during routine anaesthesia and to whether under such circumstances alterations in cerebral

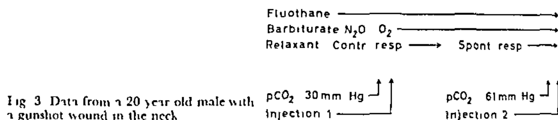


Fig 3 Data from a 20 year old male with a gunshot wound in the neck

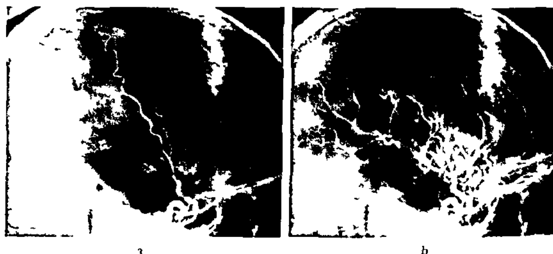
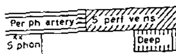


Fig 4 Carotid angiography a) Fluothane with controlled respiration pCO_2 = 30 mm Hg calibre of siphon 4 mm b) Fluothane with spontaneous respiration pCO_2 = 61 mm Hg calibre of siphon 5 mm

blood flow follow which may entail a risk of complications in patients with increased intracranial pressure

We have therefore studied the arterial pCO together with the cerebral circulation time and circulation pattern in carotid angiography, comparing different techniques for general anaesthesia in the same patient Care was taken to control and as far as possible to keep unchanged other factors such as blood pressure, pulse rate, injection time, position of catheter in the carotid artery and position of the patient

In one experiment general anaesthesia was started with barbiturate, nitrous oxide (N O) and oxygen, muscle relaxant and controlled respiration and during this period the pCO was 40 mm Hg in a blood specimen withdrawn immediately before injection 1 The anaesthetic technique was then changed The muscle relaxant was withdrawn so that spontaneous respiration recommenced and Fluothane was added Immediately before injection 2 the pCO_2 was 60 mm Hg Thus it is evident that the increase in pCO during



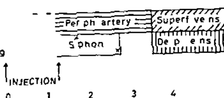


Fig 5 Circulation data from left s de in a 65 yea old female with a left s ded central vascular lesion

routinely applied anaesthetic technique may be of the order which has been shown to influence cerebral blood flow significantly

Fig 1a shows a film from series 1 and Fig 1b a film from series 2 both exposed at the same interval from the start of injection It is clearly seen that the speed of the cerebral circulation increased with elevated pCO_2 as did the calibre of the vessels

In the same patient a left sided carotid angiography was performed 14 days later This time we had no pCO determination but since the same technique was applied which had caused an increase at the first examination and since the circulation rate was obviously increased, a high arterial carbon dioxide tension probably was again present Therefore the patient was actively ventila ted for some minutes Fig 2 shows one angiogram taken during spontaneous respiration which was depressed by the drugs, and another exposed at the same interval following injection but after active hyperventilation Two interesting features noted were the marked slowing down of the circulation following hyperventilation and the marked cross circulation (No contralateral com pression was applied) Probably this phenomenon must be attributed to the increased peripheral cerebral vascular resistance HUBER (1964) has demon strated the same phenomenon in cases of head trauma with severe oedema

Fig 3 refers to another normal patient Here the pCO_2 was subnormal during routine controlled respiration and without any change in the other drugs, the change over to spontaneous respiration produced an important increase

Fig 4a shows the decreased intracranial circulation at the time of the low pCO_2 The peripheral branches of the external carotid artery filled well and the siphon was narrow Fig 4b is a comparably timed film when the carbon dioxide tension was 61 The external filling was less outstanding



Fig. 6. Films from both series at 3.9 sec. a) Fluothane with spontaneous respiration, $pCO_2 = 51$ mm Hg, superficial veins more evident. b) Fluothane with controlled respiration, $pCO_2 = 44$ mm Hg, deep veins more evident.

and the internal circulation much quicker and the calibre of the siphon had definitely increased.

Fig. 5 is a diagram showing the circulation on the left side in a 65 year old female with a left sided central vascular lesion. In this case Fluothane and spontaneous respiration was applied in the first part of the examination and controlled respiration during the latter part. The increase of pCO_2 during spontaneous respiration was less than in the preceding cases but was still well beyond the normal upper limit, and within the range shown to influence the cerebral blood flow. During controlled respiration the pCO_2 was within normal limits.

The contrast disappeared more quickly from the arteries and appeared earlier in the veins in series 1 than in series 2, but in addition a further interesting observation was made. While the deep and superficial veins filled approximately simultaneously in series 2 with a normal pCO_2, the superficial veins filled definitely earlier and the deep ones later in series 1. The explanation may be that due to the deeply situated pathological process the adjacent part of the vascular bed could not respond adequately to the increased pCO_2, and therefore the blood was deviated through the superficial vessels in the unaffected areas.

A film from each series at 3.9 sec is shown in Fig. 6. With the increased pCO_2 the filling of the superficial veins was obviously dominant.

Conclusions

Our observations show that even during routinely conducted general anaesthesia rather wide variations in the pCO_2 may occur. These variations are followed by important changes in the cerebral circulation rate and there may also be alteration of the circulation pattern. Knowledge of these facts is important from a diagnostic point of view and it may be one explanation of the great spread of the normal circulation times during cerebral angiography given by different authors.

More important however is that such changes in the cerebral blood flow may cause deleterious effects in patients with increased intracranial pressure. In such cases a dilatation of the vessels may precipitate tentorial herniation. Certainly there exist cases where such complications have been attributed to the angiographic procedure instead of to the anaesthesia.

SUMMARY

Circulation time and circulation pattern in cerebral angiography have been studied comparing different techniques of general anaesthesia in the same patient. Very wide variations in the cerebral blood flow were observed. This is ascribed to the rather important variations in the arterial pCO_2 which may occur during routine anaesthesia.

ZUSAMMENFASSUNG

Es wurden die Zirkulationszeit und die Gefasse im cerebralen Angiogramm studiert, wobei verschiedene Technik von Allgemeinanasthesie am selben Patient miteinander verglichen wurde. Es wurden sehr grosse Variationen der cerebralen Blutzirkulation beobachtet. Dies wird den wichtigen Schwankungen des arteriellen pCO die wahrend Rutinanasthesie auftreten konnen zugeschrieben.

RÉSUMÉ

Les auteurs ont étudié le temps de circulation et le type de circulation en angiographie cérébrale en comparant différentes techniques d'anesthésie générale chez le même sujet. Ils ont observé de très grandes variations du débit sanguin cérébral. Ceci est attribué aux variations assez importantes de la pCO_2 artérielle qui peuvent se produire au cours de l'anesthésie ordinaire.

REFERENCES

HARPER, A. M., GLASS, H. I., STEVEN, J. L. and GRANAT, A. H.: The measurement of local blood flow in the cerebral cortex from the clearance of xenon. J. Neurol. Neurosurg. Psychiat. 27 (1964) 255.

HUBER, P.: Die Bedeutung der Doppelfullung bei der Karotisangiographie. Fortschr. Rontgenstr. 100 (1964) 114.

Kety S S and Schmidt C F The effects of altered arterial tensions of carbon dioxide and oxygen on cerebral blood flow and cerebral oxygen consumption of normal young men J Clin Invest 27 (1948) 484

Kruger T P Rockoff D Thomas L J and Ommaya A K The effect of changes of end expiratory carbon dioxide tension on the normal cerebral angiogram Amer J Roentgenol 40 (1963) 506

Lassen N A Hoedt Rasmussen K Sorensen S C et coll Regional cerebral blood flow in man determined by krypton 85 Neurology 13 (1963) 719

Novack P Shenkin A K Bortin L et coll The effects of carbon dioxide inhalation upon the cerebral blood flow and cerebral oxygen consumption in vascular disease J Clin Invest 32 (1953), 696

Sokoloff L The action of drugs on the cerebral circulation Pharmacol Rev 11 (1959) 1

Tonnis W und Schiefer W Zirkulationsstorungen des Gehirns im Serienangiogramm Springer Verlag Berlin 1959

FROM THE DEPARTMENT OF NEURORADIOLOGY, NEWCASTLE GENERAL HOSPITAL
NEWCASTLE UPON TYNE ENGLAND

CONTROLLED TRIAL OF CERTAIN CONTRAST MEDIA IN CEREBRAL ANGIOGRAPHY

by

ARNOLD APPLEBY and GORDON L. GRYSPEERDT

With the increasing emphasis on the study of the smaller branches of the cerebral vessels for detailed diagnostic accuracy in cerebral angiography, the choice of the most suitable contrast medium has become even more important. Few workers have made any controlled comparison of the definition of the smaller cerebral arteries obtained with the numerous contrast media now available. The present investigation was planned to compare the angiographic quality of several *different* tri-iodo compounds containing the same amount of iodine *per unit volume* and the study was confined to percutaneous carotid angiography.

Method. Employing the double injection method of stereoscopy in the lateral projection which we use as a routine in the investigation of cases with suspected space occupying lesions, a different contrast medium was given for each injection of the stereoscopic pair. Alternate examinations received alternate media for the first injection.

Percutaneous puncture of the common carotid artery or internal carotid artery was performed using a No. 18 needle and 9 ml of the contrast medium

Table 1

Trial I — Comparison of Urografin 60 % with Hypaque 45 %

	Observer A	Observer B	Agreement between A and B
Urografin preferred	32	20	13
Hypaque preferred	4	[illegible]	0
No difference	30	41	25
Total cases	66	66	38
Significance of preference for Urografin	$p < 0.001$	$p < 0.005$	$p < 0.001$

at blood temperature were introduced at each injection All examinations were carried out under general anaesthesia which prevented any movement of the subject or displacement of the needle tip due to swallowing between injections Any case in which readjustment of the needle was required, or in which there was alteration of the radiographic factors between the two series of exposures, was immediately excluded from the trial No cases with proven subarachnoid haemorrhage or recent head injury were included in the investigation

At the end of each trial, the relevant films of the cases were collected and displayed with all identification marks obscured, and two experienced observers separately compared the contrast density and definition of the small arteries in three pre determined regions in each stereoscopic pair The vessels chosen for this study were the anterior choroidal artery, the small branches of the calloso marginal artery and the small branches of the posterior parietal artery

The preference if any, for each group of vessels in one or other half of the stereoscopic pair was noted by each observer and his final preference in each individual case was determined by any preponderance in the detailed assessment All the films were separately scrutinised before any of the identification marks were uncovered The preferences of each observer were then tabulated and the results subjected to statistical analysis, both individually and combined

Trial I

In the first trial Urografin 60 % was compared with Hypaque 45 % Urografin 60 % contains 52 % N methylglucamine diatrizoate and 8 % sodium diatrizoate in aqueous solution, whereas Hypaque 45 % contains only sodium diatrizoate in aqueous solution Urografin 60 % however, contains 29 % of iodine per unit volume whereas Hypaque 45 % contains only 27 % of iodine per unit volume

Table 2

Trial II — Comparison of Conray 60% with Angio-Conray 46.6%

	Observer A	Observer B	Agreement between A and B
Conray preferred	56	27	20
Angio-Conray preferred	8	9	2
No difference	37	65	30
Total cases	101	101	52
Significance of preference for Conray	$p < 0.001$	$p < 0.005$	$p < 0.001$

Results Observer A preferred Urografin in 32 angiograms Hypaque in 4 and found no difference in 30 Observer B preferred Urografin in 20 angiograms, Hypaque in 5 and found no difference in 41 The two observers agreed about the classification in 38 cases in 25 there was considered to be no difference between the two contrast media and in 13 cases Urografin was considered to be superior In no case was Hypaque preferred by both observers

The differences between the two contrast media were extremely small in degree and it was in fact very difficult for either observer to detect any significant difference in many cases In no case was it felt that the difference was such that the diagnostic interpretation of the cases examined was made easier with one contrast medium than with the other

Statistical analysis The first observer found Urografin better in 32 cases and Hypaque better in 4 cases These 36 cases alone are used for significance testing On the null hypothesis that in cases in which a preference is expressed half will be in favour of each material the probability of this result is less than 1 in 10^5 The result for this observer is thus highly significant

The second observer found differences in 25 cases preferring Urografin in 20 cases and Hypaque in 5 cases The probability of this result is 5 in 10^3 The result for this observer is thus also statistically significant

If the analysis is confined to those cases in which both observers agreed as to preference it is found that agreement occurred in 38 cases of which there were 13 preferences for Urografin and none for Hypaque The probability of this is 2 in 10^4 indicating a highly significant preference for Urografin (Table 1)

Trial II

In this trial in order to avoid a possible source of confusion the amount of iodine was exactly equalised in the two contrast media under test The media chosen were Conray 60% and a specially prepared solution of Angio Conray

Table 3

Trial III — Comparison of Conray 61 7 %, with Urografin 60 %

	Observer A	Observer B	Agreement between A and B
Conray preferred	10	9	3
Urografin preferred	12	9	4
No difference	46	50	37
Total cases	68	68	44
Significance of preference	n s	n s	n s

46 6 % both media containing 28 % of iodine per unit volume Conray is methylglucamine iothalamate in aqueous solution and Angio Conray is sodium iothalamate in aqueous solution

Results Again the differences in the quality of the angiograms were extremely slight, and in no case was it felt that the diagnostic interpretation was made easier with the one contrast medium than with the other

Observer A preferred Conray in 56 angiograms and Angio Conray in 8 and found no difference in 37 Observer B preferred Conray in 27 angiograms Angio Conray in 9 and found no difference in 65 The two observers agreed about the classification in 52 cases, in 20 of these Conray was preferred in 30 there was no difference and in only 2 cases was Angio Conray preferred by both observers

Statistical analysis of this trial showed a highly significant preference for Conray of the same order as that obtained for Urografin in Trial I (Table 2)

Trial III

In the third stage of the investigation it was decided to compare the preferred medium from Trial I with the preferred medium from Trial II Urografin 60 % (methylglucamine diatrizoate) was therefore compared with a specially prepared solution of Conray 61 7 % (methylglucamine iothalamate) both media containing 29 % of iodine per unit volume

Although these two substances are isomeric a toxic effect from their administration within a few seconds of each other could not be completely excluded Experiments on anaesthetised cats however showed no alteration in the usual response to intra arterial contrast media and it was therefore deemed safe to carry out the trial

Results Observer A preferred Urografin in 12 angiograms Conray in 10 and found no difference in 46 Observer B preferred Urografin in 9 angiograms Conray in 9 and found no difference in 50 The two observers agreed about the classification in 44 cases in 37 of these there was no difference in 4 cases Urografin was preferred and in 3 cases Conray was preferred

Statistical analysis of this trial showed no significant preference for either contrast medium (Table 3)

Analysis of all trials

Four different contrast media were tested in three trials and any differences in definition and contrast density detected in the various media in the small cerebral arteries were found to be extremely slight in degree in all the trials This is shown by the number of cases in which the two observers disagreed and by the numerous cases in which no difference was detected by either observer (Tables 1 2 and 3)

In Trial I a highly significant preference for the medium containing methyl glucamine diatrizoate over the medium containing only sodium diatrizoate was found In Trial II there was a similar highly significant preference for the contrast medium containing methylglucamine iothalamate over the medium containing only sodium iothalamate

When the two media which were preferred in Trials I and II were tested against each other in solutions of equal iodine content in Trial III (one medium containing methylglucamine diatrizoate and the other containing methyl glucamine iothalamate) no statistical preference for either medium was found

Separate analyses of the results of the trials in relation to the 'up shift and the down shift of the stereoscopic pairs and also in relation to the first and second injections irrespective of the contrast medium used consistently showed no statistical preferences

Discussion

There are surprisingly few reports in the literature of comparative studies of the angiographic quality of various contrast media carried out by controlled trials Most workers have combined an investigation of the toxic effects and the angiographic quality of various media by making comparison in separate series of subjects but a few have used double injection techniques in the same subject in which a controlled comparison has been possible The findings of the various authors concerning angiographic quality are difficult to assess as the results are usually expressed in general terms without statistical analysis and some conflict of opinion between authors is found

Table 4

Details of contrast media tested in the trials

Medium	Composition	Viscosity at 37.5° C (in centipoise)
Conray 61.7 % (w/v)	Methylglucamine iothalamate	4.8
Conray 60 % (w/v)	Methylglucamine iothalamate	4.0
Urografin 60 % (w/v)	*Methylglucamine* diatrizoate 52 % + Sodium diatrizoate 8 %	4.0
Angio Conray 46.6 % (w/v)	Sodium iothalamate	2.2
Hypaque 45 % (w/v)	Sodium diatrizoate	2.1
Blood		2.7 (mean)

Grote & Bettag (1955) carried out clinical tests comparing Urografin for tolerance and contrast depth with Perabrodil M (methylglucamine 3,5 diiodo 4 pyridone N-acetate). These authors compared Perabrodil M 45 % with Urografin 60 %, on comparison of the contrast density of these concentrations, Urografin was found to be superior. The difference in contrast density of the two media on comparison of 60 % solutions of each was not so great but was still in favour of Urografin. However, Grote & Bettag in their series were comparing a di iodo compound with a tri iodo compound.

Dochner & Brugger (1960) compared 50 angiograms using 60 % methyl glucamine diatrizoate (Renografin), 50 angiograms using 50 % sodium acetrizoate (Urokon), and *10* angiograms using *50 % sodium diatrizoate* (Hypaque). The arterial, capillary and venous phases of each examination were evaluated by a radiologist and a neurosurgeon separately. The density of the contrast medium in the angiograms obtained with sodium acetrizoate (Urokon) was found to be slightly less than that of those angiograms using methylglucamine diatrizoate (Renografin). When the small number of sodium diatrizoate angiograms was compared with the methylglucamine diatrizoate angiograms the density was found to be of equal degree in the arterial and *capillary phases but methylglucamine diatrizoate* was slightly superior in the venous phase. This superiority in the venous phase was felt by the authors to be due to the slightly higher viscosity of the methylglucamine salt resulting in slightly less dilution of the opaque medium.

A comparison was made between Isopaque 45 % (sodium metrizoate) and Hypaque 45 % *in carotid and vertebral angiography by* Bull & Murray

LESLIE (1962) In their carotid series these workers carried out successive injections first of one medium and then of the other into the same artery with only one puncture Comparison of the carotid angiograms obtained with the two media revealed no difference in quality These workers were however, comparing two sodium salts

KENDALL (1964) examined 100 patients undergoing carotid or vertebral angiography using Conray In this series 50 of the patients received injections both of Conray 60 % and of Hypaque 45 % while this double injection was mainly carried out in order to test the degree of discomfort experienced by the patient a direct comparison of the angiograms must have been possible in these 50 cases KENDALL states that the contrast density achieved with Conray was excellent but no better than that obtained by using Urografin or Hypaque

MARSHALL & LING (1963) as part of a very extensive clinical trial of Conray and Angio Conray in all types of angiographic procedures performed cerebral angiography using Conray 60 % in 210 patients These authors state that the contrast density was superior to that obtained with other contrast media

A comparison of the quality of angiograms obtained with Hypaque 45 % and Urografin 60 % was carried out by BROADBRIDGE & LESLIE (1958) They found no significant difference in the level of contrast obtained with the two media but observed that Urografin was rather more viscous *in the syringe*

In the present investigation we realised from our preliminary study of the angiograms and from the variation in the results of the comparative *studies* in the literature that the differences between the various media were very slight Thus when we came to carry out the blind selection we were searching for extremely minor differences in contrast This may account for our results differing from those of KENDALL (1964) and from those of BROADBRIDGE & LESLIE (1958) Our results agreed with those of MARSHALL & LING (1963) and with DOCHNER & BRUGGER (1960) in that we preferred the methylglucamine salts

Solutions of methylglucamine salts are more viscous than solutions of the corresponding sodium salts and it is likely that the enhanced bolus effect of the more viscous medium is a major contributory factor to the better definition of the small arteries The viscosities of the various contrast media in the concentrations employed in the trials are listed in Table 4

Although the differences in the radiographic quality of the various contrast media detected by Trials I and II in the present investigation were very slight and the better media did not appear to enhance the diagnostic interpretation in the cases examined the finding of a highly significant preference for certain contrast media is important The small vessels studied in this investigation were deliberately chosen as they are easily identifiable in all successful cerebral

angiograms by carotid angiography However, some of the small central branches of the cerebral arteries may be difficult to identify in both carotid and vertebral angiography, especially in the antero posterior projections, even with the help of subtraction methods The present investigation was therefore planned to determine the most suitable contrast medium for study of the small central vessels If the viscosity of the contrast medium is a major factor in influencing the contrast density in these vessels it may be that the optimum value for this factor has yet to be found

Since all the subjects in the three trials received injections of two media no attempt to compare the toxicity or side effects was made However, no immediate unfavourable sequelae, such as a marked drop in blood pressure or apnoea, were encountered in any of the cases examined in this series

Acknowledgments

We wish to thank Dr D J Newell of the Nuffield Department of Industrial Health University of Newcastle upon Tyne for the statistical analysis We would also like to express our thanks to May and Baker Ltd for carrying out the animal experiments

SUMMARY

A controlled comparison of the radiographic definition of the smaller arteries in cerebral angiograms obtained with certain contrast media has been carried out A highly significant statistical preference for those media containing the methylglucamine salt over those containing the corresponding sodium salt was observed on careful scrutiny by two separate assessors No statistical preference was found on comparison of two media containing the methyl glucamine salts (Urografin and Conray) in solutions of equal iodine content

ZUSAMMENFASSUNG

Es wurden die kleinen Arterien im cerebralen Angiogram bei Verwendung bestimmter Kontrastmittel miteinander verglichen Kontrastmittel die Methylglukaminsalze enthalten sind denen mit dem entsprechenden Natriumsalz bei weitem vorzuziehen Diese Beobachtung konnte von zwei von einander unabhängigen Untersuchern gemacht werden und hat sich als statistisch hoch signifikant erwiesen Eine statistisch gesicherte Überlegenheit eines zweier Kontrastmittel von Methylglukaminsalzen mit gleichem Jodgehalt (Urografin und Conray) konnte jedoch nicht festgestellt werden

RÉSUMÉ

Les auteurs ont fait une comparaison contrôlée de la définition radiographique des plus fines artères sur les angiographies cérébrales faites avec certains moyens de contraste L examen soigneux par deux juges séparés a donné une préférence statistiquement très significative pour les moyens de contraste contenant le sel de méthylglucamine sur ceux contenant le sel de sodium correspondant La comparaison de deux moyens de contraste contenant les sels de méthylglucamine en solutions de même teneur en iode (Urografin et Conray) n a pas montré de préférence statistique

REFERENCES

BROADBRIDGE A T and LESLIE E V Cerebral angiographic contrast media Brit J Radiol 31 (1958) 556

BULL J W D and MURRAY LESLIE R M Experience with metrizoate sodium (Isopaque) in cerebral angiography Farmakoterapi 18 (1962) 24

DOCHNER G A and BRUGGER G E Comparison of diatrizoate methylglucamine sodium acetrizoate and diatrizoate sodium in cerebral angiography N Y St J Med 60 (1960) 4072

GROTE W and BETTAG W Observations on the use of Urografin in cerebral angiography Fortschr Rontgenstr 83 (1955) 580

KENDALL B E Cerebral angiography using Conray Brit J Radiol 37 (1964) 581

MARSHALL T R and LING J T Clinical evaluation of two new contrast media Conray and Angio-Conray Amer J Roentgenol 89 (1963) 423

angiograms by carotid angiography However, some of the small central branches of the cerebral arteries may be difficult to identify in both carotid and vertebral angiography, especially in the antero posterior projections, even with the help of subtraction methods The present investigation was therefore planned to determine the most suitable contrast medium for study of the small central vessels If the viscosity of the contrast medium is a major factor in influencing the contrast density in these vessels it may be that the optimum value for this factor has yet to be found

Since all the subjects in the three trials received injections of two media no attempt to compare the toxicity or side effects was made However, no immediate unfavourable sequelae, such as a marked drop in blood pressure or apnoea, were encountered in any of the cases examined in this series

Acknowledgments

We wish to thank Dr D J Newell of the Nuffield Department of Industrial Health University of Newcastle upon Tyne for the statistical analysis We would also like to express our thanks to May and Baker Ltd for carrying out the animal experiments

SUMMARY

A controlled comparison of the radiographic definition of the smaller arteries in cerebral angiograms obtained with certain contrast media has been carried out A highly significant statistical preference for those media containing the methylglucamine salt over those containing the corresponding sodium salt was observed on careful scrutiny by two separate assessors No statistical preference was found on comparison of two media containing the methyl glucamine salts (Urografin and Conray) in solutions of equal iodine content

ZUSAMMENFASSUNG

Es wurden die kleinen Arterien im cerebralen Angiogram bei Verwendung bestimmter Kontrastmittel miteinander verglichen Kontrastmittel die Methylglukaminsalze enthalten sind denen mit dem entsprechenden Natriumsalz bei weitem vorzuziehen Diese Beobachtung konnte von zwei von einander unabhängigen Untersuchern gemacht werden und hat sich als statistisch hoch signifikant erwiesen Eine statistisch gesicherte Überlegenheit eines zweier Kontrastmittel von Methylglukaminsalzen mit gleichem Jodgehalt (Urografin und Conray) konnte jedoch nicht festgestellt werden

RÉSUMÉ

Les auteurs ont fait une comparaison contrôlée de la définition radiographique des plus fines artères sur les angiographies cérébrales faites avec certains moyens de contraste L'examen soigneux par deux juges séparés a donné une préférence statistiquement très significative pour les moyens de contraste contenant le sel de méthylglucamine sur ceux contenant le sel de sodium correspondant La comparaison de deux moyens de contraste contenant les sels de méthylglucamine en solutions de même teneur en iode (Urografin et Conray) n'a pas montré de préférence statistique

conserve L hematome extra dural par contre d apres cet auteur est plus limite en étendue et sa forme sur les cliches de face est bi convexe la cortica lite cerebrale restant ainsi concave vers l exterieur comme c est le cas pour l hematome sous dural chronique Plus tard les travaux de HIRSCH, DAVID & BORNE (1962) ont permis de definir les elements déja connus du décollement angiographique de l artere meningee moyenne dans le diagnostic d un tel hematome extra dural Plus récemment enfin les travaux de CRONQVIST & KOHLER (1963) puis de HUBER (1964) ont permis d établir avec plu d exactitude les limites de nos possibilites diagnostiques en matiere d hematome extra dural

Les precisions angiographiques que nous voudrions apporter en cas d une telle affection repo ent sur l étude de nos 45 derniers cas d hematomes extra duraux observés au service de Neuro Chirurgie de Colmar au cours de ces trois dernieres annees chez 42 malades Ces precisions angiographiques portent sur des détails de l image angiographique visibles sur les differentes phases de l angiogramme arterielle, veineuse et intermédiaire qu il s agisse de l une de ces phases séparement ou sur plusieurs ou toutes ces phases

Dans un grand nombre de nos hematomes extra duraux le diagnostic etiologique a ainsi pu etre pose dans la periode pre operatoire a l aide des cliches et des incidences standard de face et de profil sans y adjoindre les projections speciales en oblique par exemple L'hématome extra dural etant une urgence chirurgicale le diagnostic doit pouvoir etre pose rapidement et pour cette meme raison les projections speciales ne feraient qu prolonger l examen Certaines images angiographiques d autre part surtout en cas de lesions bilatérales et multiples ne donnent que des signes discrets d hematome qui sont l objet essentiel de ce travail et qui n inciteraient pas toujours le clinicien a pratiquer d autres incidences

Dans un premier chapitre assez concis nous pre enterons nos cas d héma tomes extra duraux en tenant compte d une part de leur locali ation et d autre part de la possibilite angiographique d en faire le diagnostic étiologique

Un deuxieme chapitre sera reservé aux commentaires dans lesquels nous decrirons les images angiographiques qui nous paraissent caracteristiques d un hematome extra dural

Presentation et classification de nos hématomes

1 *Hematomes hauts et medians* Il s agit de quatre cas de situation frontale empietant vers l arriere sur l os parietal l image angiographique est typique par le décollement du sinus longitudinal superieur toujours visible sur les images de profil parfois sur les incidences de face lorsque le rayon centr il passe tangentiellement a la surface de l hématome

CENTRE HOSPITALIER L. PASTEUR, COLMAR, FRANCE

LE DIAGNOSTIC ANGIOGRAPHIQUE DE L'HÉMATOME EXTRA-DURAL ET SES DIFFICULTÉS

par

J. BAUMGARTNER, E. WORINGER, J. P. BRAUN et D. LE MAISTRE

L'hématome extra-dural est une affection traumatique dont la symptomatologie clinique est bien codifiée. En réalité cette symptomatologie classique ne se révèle pas toujours aussi exacte depuis que les cas de traumatisme crânien devenus plus fréquents sont centralisés dans les services spécialisés et donc mieux connus. Ainsi tel intervalle libre après traumatisme crânien a pu être attribué à un hématome intra-parenchymateux ou sous-dural aigu et un hématome extradural a pu être découvert chez un malade traumatisé crânien depuis quelques jours.

L'angiographie carotidienne, examen routinier en cas de traumatisme crânien, a fait l'objet de nombreux travaux concernant l'hématome extra-dural. Nous ne citerons que les noms de LINDGREN (1954) qui disait que l'hématome extra-dural ressemblait à l'hématome sous-dural et ne s'individualisait *que dans les localisations hautes et médianes par décollement* du sinus longitudinal supérieur de la paroi crânienne. Cette notion ne confirmait d'ailleurs que celle déjà émise par WICKBOM (1949) et ENGESET (1950). NORMAN (1956) a fait un essai de différentiation entre l'hématome extra-dural et celui de situation sous-durale en montrant que leur forme et leur étendue n'étaient pas les mêmes. L'hématome sous-dural aigu est plus étendu le long de la convexité cérébrale dont l'aspect convexe sur les clichés angiographiques de face reste

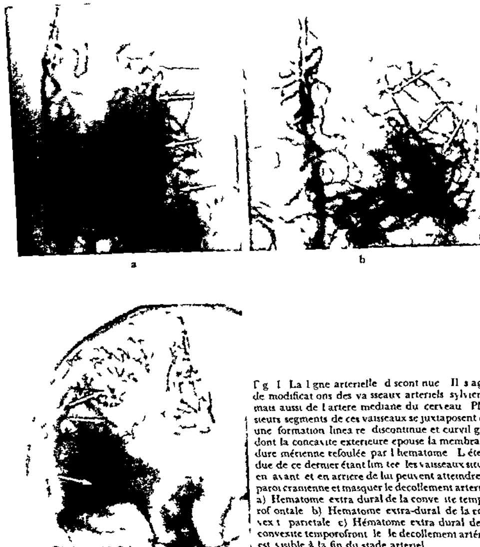


Fig 1 La ligne arterielle discontinue Il s agit de modifications des vaisseaux arteriels sylviens mais aussi de l artere mediane du cerveau Plusieurs segments de ces vaisseaux se juxtaposent en une formation lineaire discontinue et curviligne dont la concavite exterieure epouse la membrane dure mérienne refoulée par l hematome L étendue de ce dernier étant limitee les vaisseaux situés en avant et en arriere de lui peuvent atteindre la paroi cranienne et masquer le decollement arteriel a) Hematome extra dural de la convexite temporofontale b) Hematome extra-dural de la convexite parietale c) Hématome extra dural de la convexite temporofrontale le decollement artériel est visible à la fin du stade arteriel

et intermédiaire Si on ne dispose pas de ces cinq cliches il est parfois necessaire de repéter l examen afin d obtenir tous les stades angiographiques et essentiellement les stades intermediaires

B La ponction de l artere carotide primitive doit etre preferée a celle de l artere carotide interne en cas de traumatisme cranien Elle permet l opaci

2 *Hématomes hauts et para médians* Il s'agit de ceux situés pres de la ligne médiane sans avoir décollé le sinus longitudinal supérieur Sur nos quatre cas de cette variete d'hématomes, trois étaient de situation frontale et un de localisation pariétale Le diagnostic étiologique pré opératoire, a été posé chez trois parmi eux sur les incidences de face et chez le quatrieme (de situation frontale) sur les incidences de face et de profil

3 *Hematomes de la base* Sur les neuf cas de cette variéte d'hematomes, un etait situé sous le lobe frontal et huit sous le lobe temporal L'hematome frontal et trois hematomes de situation temporale presentaient un aspect angiographique extra dural typique Les autres ne se differenciaient pas de l hématome sous dural aigu ou intra parenchymateux Un parmi les malades ayant présente un tel hematome sous temporal était par ailleurs atteint d un hématome hetero latéral de la variete externe du paragraphe suivant

4 *Hematomes de la convexité latérale de l'hémisphere cérébral* Ces hematomes ont en commun leur situation latérale au niveau de la région fronto parieto temporo occipitale Ils peuvent empiéter sur l une ou l'autre de ces regions soit de l'avant vers l arriere ou de la ligne médiane vers la base du crane Il s'agit de vingt huit hematomes observes chez vingt six malades Deux parmi ces malades presentaient un hématome extra dural bilatéral de la variété laterale, un troisieme malade presentait un hématome extra dural bilatéral dont un de la variete latérale et l autre de la variete temporo basale citée dans le paragraphe précédent Vingt six fois sur ces vingt huit cas de cette variéte externe l hématome extra dural a ete reconnu au stade pré opératoire Parmi les deux cas non diagnostiques ayant l intervention, une fois l hématome a éte visible angiographiquement mais malheureusement apres que le diagnostic en fut posé à l autopsie, le second de ces cas a été reconnu en cours d'intervention et n a pas été visible angiographiquement

Commentaires

Les reflexions qui découlent de l étude angiographique de nos hématomes concernant quatre ordres de faits (1) la technique angiographique, (2) le contexte clinique, (3) la topographie de l hématome, et (4) les signes angiographiques

1 *La technique angiographique*

A Afin de reunir avec beaucoup de régularite le maximum de signes angiographiques d un hématome extra dural, il est utile de disposer d une sériographie d au moins cinq cliches de face et cinq cliches de profil Cette sériographie permet d englober tous les stades angiographiques artériel, veineux

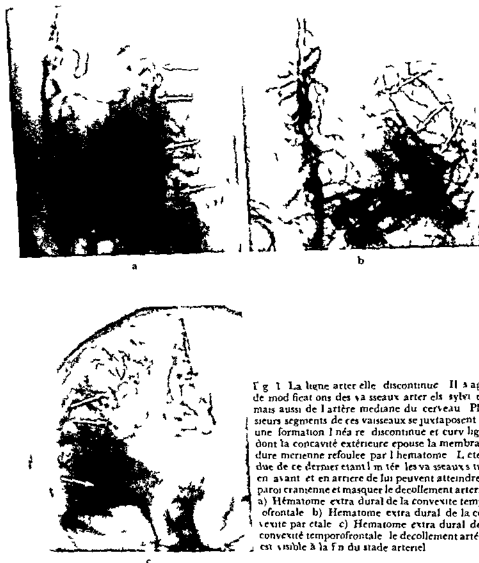


Fig 1 La ligne arterielle discontinue Il s agit de modifications des vaisseaux arteriels sylviens mais aussi de l artère mediane du cerveau Plusieurs segments de ces vaisseaux se juxtaposent en une formation linéaire discontinue et curviligne dont la concavité extérieure epouse la membrane dure merienne refoulee par l hematome L etendue de ce dernier etant limitée les vaisseaux situes en avant et en arriere de lui peuvent atteindre la paroi cranienne et masquer le decollement arteriel a) Hématome extra dural de la convexite temporofrontale b) Hematome extra dural de la convexite parietale c) Hematome extra dural de la convexité temporofrontale le decollement artériel est visible à la fin du stade arteriel

et intermediaire Si on ne dispose pas de ces cinq clichés il est parfois necessaire de répeter l examen afin d obtenir tous les stades angiographiques et essentiellement les stades intermediaires

B La ponction de l artere carotide primitive doit etre préferee a celle de l artere carotide interne en cas de traumatisme cranien Elle permet l opaci

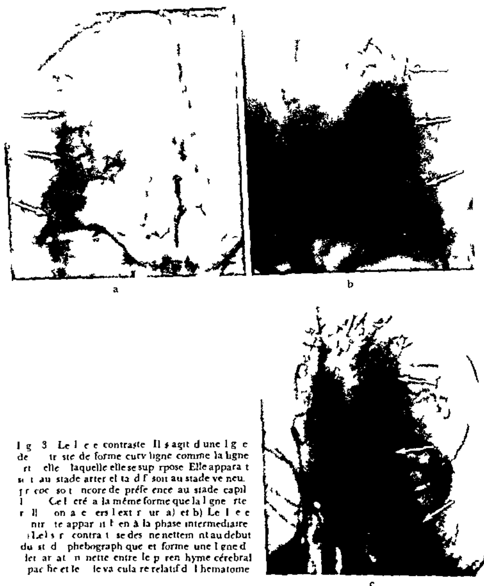


Fig. 2. La ligne artérielle discontinue (sur une incidence de profil). Il s'agit d'un hématome parietal paramédian. Dans cette variété d'hématomes le décollement artériel est toujours visible sur les incidences de profil, parfois sur les incidences de face et de profil.

fication des branches de l'artère carotide interne et celles de l'artère carotide externe. Même si les extrémités distales de ces branches ne sont pas toujours reconnues individuellement en raison de la surcharge du cliché radiographique, elles peuvent contribuer parfois sur un petit segment de leur parcours à former avec les autres segments d'autres branches, un signe angiographique non négligeable d'un tel hématome extra dural comme nous le verrons ultérieurement.

2. *Le contexte clinique*

L'interprétation correcte des angiographies exige la connaissance du fait clinique à savoir l'existence d'un traumatisme crânien relativement récent allant jusqu'à quelques jours. Cette notion est importance car certains signes angiographiques qui nous paraissent caractéristiques de l'hématome extra dural ne le sont qu'à condition qu'il y ait cette notion de traumatisme récent. En effet ces signes peuvent exister en dehors de l'hématome extra dural tel par exemple la ligne artérielle discontinue ou la ligne de condensation contrastée (ces signes seront explicités ultérieurement) qui peuvent se manifester dans d'autres circonstances. Tel est le cas par exemple de la ligne de condensation contrastée chez l'hématome sous dural chronique.



I g 3 Le l e e contraste Il s agit d une l g e de tr ste de forme curv ligne comme la ligne rt elle laquelle elle se sup rpose Elle appara t s t au stade arter el ta d f soit au stade ve neu j r coc so t ncore de préfe ence au stade capil l Ce l eté a la même forme que la l gne rte r ll on a e ers l ext r ur a) et b) Le l e e ntr te appar it l en à la phase intermediaire l Le l s r contra t se des ne nettem nt au debut du st d phebograph que et forme une l gne d let ar at n nette entre le p ren hyme cérebral pac fie et le le va cula re relatif d l hematome

3 *La topographie de l'hematome*

Cette topographie est importante a connaitre non seulement pour des raisons opératoires mais aussi et avant tout pour des causes diagnostiques En effect comme il ressort de l étude de nos cas le diagnostic d hematome extra dural peut etre pose avec beaucoup de regularite et de certitude dans

certaines localisations qui sont (1) dans les variétés hautes et médianes par le refoulement du sinus longitudinal supérieur (2) dans les variétés hautes et para médianes par un certain nombre de signes soit déjà connus et que nous rappellerons et certains autres que nous décrirons dans le paragraphe suivant, (3) dans les variétés latérales de toute la convexité cérébrale comme pour la variété précédente nous rappellerons ou décrirons les signes dans le paragraphe suivant

Contrairement à ces trois variétés où l'hématome extra dural peut être reconnu avec beaucoup de régularité, ceux de la base le sont moins souvent et ne peuvent, sauf à de rares exceptions près, pas être différenciés de l'hématome sous dural ou intra parenchymateux

1 *Les signes angiographiques proprement dit*

Bien qu'il s'agisse de la partie la plus importante de ce travail, nous les citerons très brièvement Ces signes ont pour certains déjà été décrits, pour d'autres nous paraissent nouveaux Ils peuvent exister isolément ou simultanément soit sur le même cliché soit sur des clichés différents On y distinguera ainsi selon les cas

A *La ligne artérielle discontinue* (Fig 1 et Fig 2) Il s'agit de modifications des vaisseaux artériels essentiellement du groupe sylvien mais aussi de l'artère péricallose Ces modifications sont visibles sur les clichés de face pour la variété latérale des hématomes et de profil et parfois de face pour la variété des hématomes hauts et para médians Cette ligne artérielle discontinue est une formation artérielle linéaire formée par plusieurs segments artériels provenant de plusieurs branches de l'artère sylvienne ou de l'artère cérébrale antérieure et qui sont la cause de la discontinuité de cette ligne Ces segments artériels donc se juxtaposent en prenant une forme linéaire discontinue et légèrement curviligne Sur les clichés de face cette ligne artérielle présente une concavité extérieure correspondant à la dure mère, qui subit la poussée de l'hématome Sur les clichés de profil cette ligne est concave vers le haut et vers l'arrière pour les hématomes paramédians postérieurs et plutot concave vers le haut et vers l'avant pour les hématomes para médians antérieurs La formation de cette ligne artérielle discontinue est certainement favorisée par le refoulement régulier et curviligne de la membrane dure mérienne par l'hématome

B Le second signe de l'hématome extra dural est également un signe artériel puisqu'il s'agit du *refoulement de l'artère méningée* moyenne Ce signe a déjà été décrit Notons simplement que l'artère méningée moyenne ne peut pas toujours être individualisée et que lorsqu'elle est présente elle n'est pas toujours intéressée par le refoulement de l'hématome Il s'agit donc d'un signe ayant une valeur pathognomonique lorsqu'il est présent mais qui est



Fig 4 Refoulement des veines corticales en regard de l hematome extra dural qui se traduit par ailleurs par un vide vasculaire relatif

malheureusement fréquemment absent et devient ainsi de par son inconstance un signe moins intéressant

C *Le vide vasculaire* relatif (Fig 3 c et Fig 4) apparait frequemment au cours de la phase capillaire ou intermediaire a l endroit meme ou siege l hematome Ce vide relatif peut contraster par une ligne de démarcation plus ou moins nette avec le parenchyme cérébral qui presente une meilleure opacification

D A cette ligne de demarcation correspond dans un bon nombre de cas la *ligne de condensation contrastee* (Fig 3) Celle ci apparait souvent soit a la fin du stade arteriel soit au cours de la phase intermediaire ou aucune phase ni artérielle ni veineuse n est veritablement reconnue Cette ligne de condensation est parfois egalement visible sur d autres cliches de la seriographie Elle est habituellement en rapport avec la surprojection tangentielle de plusieurs elements vasculaires opacifies tel le stade terminal de la ligne arterielle discontinue, la demarcation entre le vide vasculaire relatif et le parenchyme cerebral mieux opacifie l artère méningee moyenne sur un de ses segments meme si elle n est pas bien individualisee ou encore certains élements veineux Elle est caracteristique de l hematome extra dural a condition qu il existe la notion de traumatisme cranien recent Cette ligne est comparable et ressemble à celle qui sépare en cas d hématome sous dural chronique l hematome de la convexité cérébrale

F Au stade veineux un *refoulement d une veine corticale* (Fig 4) est parfois visible en regard de cette ligne de démarcation entre hématome et parenchyme

cérébral. Ce refoulement est moins caractéristique et ne permet pas à lui seul le diagnostic d'hématome.

F. Une *extravasation du produit de contraste* dans la poche hématique. Il s'agit d'un signe déjà bien connu et caractéristique. C'est cette extravasation du produit de contraste qui permet parfois de poser avec certitude le diagnostic d'hématome extra-dural lorsque ce dernier a un siège basal.

G. Le dernier signe et le premier à avoir été décrit, il s'agit du *décollement du sinus longitudinal supérieur* de la paroi crânienne, en cas d'hématomes hauts et médians.

Il est utile de connaître tous ces signes qui peuvent contribuer au diagnostic d'hématome extra-dural. Ces signes peuvent exister isolément ou simultanément, même dans les cas où aucun décollement des vaisseaux de la paroi crânienne n'est visible et donc dans les cas où il n'existe pas de vide vasculaire du à l'hématome. Cette éventualité n'est pas rare en cas de lésions cérébrales bilatérales.

RÉSUMÉ

Sur une série de 45 examens angiographiques d'hématomes extra-duraux, les auteurs ont pu reconnaître régulièrement les hématomes médians qui décollent le sinus longitudinal supérieur de la paroi crânienne, les hématomes para-médians et les hématomes latéraux de la convexité cérébrale. Ces deux dernières variétés présentent des signes caractéristiques qui sont la ligne artérielle discontinue et la ligne de condensation contrastée auxquels s'ajoutent parfois d'autres signes déjà connus. Les hématomes extra-duraux de la base ne peuvent généralement pas être distingués par l'angiographie des hématomes sous-duraux ou intra-parenchymateux.

SUMMARY

In a series of 45 angiographic examinations of extradural hematomas the authors regularly recognized three types: median hematomas that separate the superior longitudinal sinus from the cranial wall, para-median hematomas and lateral hematomas of the cerebral convexity. The last two varieties produce characteristic signs including discontinuation in the arterial course and density of contrast medium. Other signs already known are also occasionally seen. Extradural basal hematomas cannot as a rule be distinguished by angiography from subdural or intracerebral hematomas.

ZUSAMMENFASSUNG

In einer Serie von 45 angiographischen Untersuchungen extraduraler Hämatome haben die Verfasser regelmässig drei Typen erkennen können: mediane Hämatome, die den oberen longitudinalen Sinus von der Schädelwand trennen, para-mediane Hämatome und laterale Hämatome über die Konvexität. Die letzten zwei Varianten geben characteristische Zeichen, so wie Unterbrechung der Arterien und Veränderung der Kontrastmitteldichte. Andere bereits bekannte Zeichen sind auch von Zeit zu Zeit zu sehen. Extradurale basale Hämatome können in der Regel nicht von subduralen oder intra-parenchymatösen Hämatomen mittels Angiographie unterschieden werden.

REFERENCES

CRONQVIST S and KOHLER R Angiography in epidural haematomas Acta radiol D 1 (1963) 42

ENGESET A On roentgen examination in head trauma Acta radiol 34 (1950) 288

HIRSCH J F DAVID M et BORNE G Un signe angiographique des hématomes extra-duraux Neuro-chirurgie 5 (1962) 91

HUBER P Die Zerebrale Angiographie beim frischen Schadel Hirn Trauma Thieme Verlag Stuttgart 1964

LINDGREN E Roentgenologie in Handbuch der Neurochirurgie Bd 2 Edit von Olivecrona und Tonnis Springer Berlin 1954

NORMAN O Angiographic differentiation between acute and chronic subdural and extra dural haematomas Acta radiol 46 (1956) 371

WICKBOM J Angiography in post traumatic intracranial hemorrhage Acta radiol 32 (1949) 249

FROM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY, THE MEMORIAL HOSPITAL
FOR CANCER AND ALLIED DISEASES, NEW YORK CITY, U S A

ANGIOGRAPHY FOR EXTRACRANIAL TUMORS

by

ARNOLD BERRETT

We have found angiography to have many important and practical applications in the management of certain extracranial tumors (BERRETT 1963) The indications may be discussed under three headings pre operative, post operative, and regional infusion techniques (intra arterial)

Pre-operative indications

Mass lesions of the head and neck of uncertain origin Angiography is of value in demonstrating the feeding vessels, degree of vascularity and anatomical extent of the tumor In certain cases it may even aid in the diagnosis A few tumors have a characteristic angiographic appearance, for example carotid body tumors, but others show little or no deviation from the normal As a general rule, in a given tumor the vascular areas are the more malignant This may indicate the best site for biopsy

Vascular occlusion Any large mass situated on the lateral aspect of the neck may encircle and compress the carotid artery causing various degrees of occlusion In such cases it is frequently difficult to determine clinically whether the carotid artery is patent or not An example of this is illustrated in Fig 1

Lesions of the vault or base of the skull with possible intracranial extensions Occa



Fig 1 B achial ang og ams a) A p view The commencement of the carotid a tery s normal but more distally the vessel is compressed by an extensi e m tastas s from a carcinoma of the ight tonsil b) Lateral view A nar ow threadlike seg nent of the i iternal carot d artery is seen More d stally the lumen becomes wider and more normal in c l ber

sionally one is presented with a soft tissue mass of the scalp which is associated with underlying bony destruction of the vault In such cases it may be difficult to determine whether there is in addition intracranial but extradural extension If intracranial extension does take place the angiographic appearance will depend largely on its location For example an osteolytic metastatic deposit in the midline of the vault which is associated with extradural extension will displace the superior sagittal sinus away from the inner table of the skull (Fig 2)

Post operative indications

Trauma to the carotid artery leading to vascular occlusion An example of this is seen in the following case The patient was a 44 year old male who presented with a slow growing right sided mass on the lateral aspect of the neck At

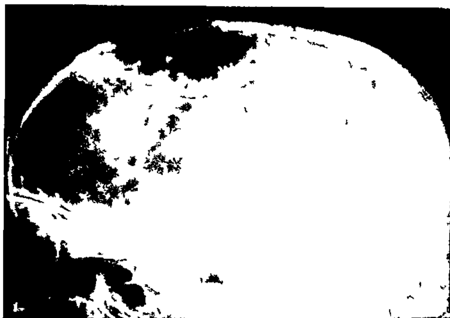


Fig. 2 Angiogram in late arterial phase showing metastasis from a hypernephroma with destruction in the vault of the skull and extradural extension The small arteries form a vascular halo around the area of extradural extension

surgery this mass was adherent to the carotid artery and very difficult to excise Histological examination revealed it to be an extracranial meningioma The patient had a stormy post operative course with features of an acute and severe cerebral vascular accident on the left hand side This ultimately led to his death Utilizing the clinical, angiographic and post mortem information at our disposal, the following appears to have taken place The carotid artery in the neck was traumatized at the time of surgery, and this resulted in sub intimal hemorrhage associated with thrombosis in the lumen This led to vascular occlusion and extensive infarction of the right side of the brain

A very careful post mortem examination failed to reveal an associated meningioma of the nervous system We therefore regard this as an example of an extremely rare meningioma occurring completely outside the nervous system

Complications in patients with known carcinoma Some of our patients with known primary carcinoma presented with neurologic findings in the post operative period We have found angiography to be of very great value for the confirmation of metastatic deposits and for the demonstration of other unrelated intracranial diseases presenting a similar picture (BERRETT 1963)

Regional infusion techniques (intra arterial)

This is now employed in several centers for protracted and continuous infusion of various chemotherapeutic agents and radioactive isotopes to the tumor bearing area It is of the utmost importance to select the most appropriate artery prior to this form of therapy and essential that the catheter is correctly placed and maintained in position (HOROWITZ 1960)

SUMMARY

The full demonstration of both the normal and pathological arterial system is of fundamental importance in the correct handling of many extracranial tumors Specific indications in both the pre and post-operative period are described

ZUSAMMENFASSUNG

Die vollständige Darstellung des normalen und pathologischen arteriellen Gefässystems ist für die richtige Behandlung bei vielen extrakraniellen Tumoren von fundamentaler Bedeutung Specifische Indikationen in der prä und postoperativen Periode werden beschrieben

RÉSUMÉ

Il est d une importance fondamentale de faire un examen complet des artères normales et pathologiques pour traiter correctement un grand nombre de tumeurs *extracraniennes* L auteur décrit les indications spécifiques de l angiographie dans les périodes pré et post opératoires

REFERENCES

BERRETT A Head and neck arteriography Trans Amer Acad Ophthal Otolaryng 67 (1963) 530

— Metastatic disease to the brain and its differential diagnosis Acta radiol I Diagnosis (1963) 206

COCKSHOTT W P and EVANS K T The place of soft tissue arteriography Brit J Radiol 37 (1964) 167

HAWKINS T D Glomus jugulare and carotid body tumors Clin Radiol 12 (1961) 199

HOROWITZ H Intra arterial therapy a review of its clinical application in malignant disease Brit J Radiol 33 (1960) 659

FROM THE DEPARTMENTS OF RADIOLOGY (DIRECTOR PROF. H. M. STAUFFER), PHYSIOLOGY (DIRECTOR PROF. M. J. OPPENHEIMER), AND NEUROSURGERY (DIRECTOR PROF. M. SCOTT), TEMPLE UNIVERSITY MEDICAL CENTER, PHILADELPHIA, PENNSYLVANIA, U.S.A.

HIGH SPEED CINEFLUOROGRAPHY OF CERVICOCEREBRAL BLOOD FLOW PATTERNS IN DOGS

by

A. BONAKDARPOUR, P. R. LYNCH, F. MURTAGH and H. M. STAUFFER

Since the introduction of cerebral angiography by MONIZ (1927) and rapid serial angiography by CURTIS (1949) considerable data has been collected on the roentgen anatomy of both intracranial and extracranial vessels. Little radiologic physiologic information about the cervicocerebral circulation is available, however. *Since the invention of electronic x-ray image intensifiers* by COLTMAN (1948), the technique of cinefluorography (BONAKDARPOUR 1958) has been applied to investigate the physiology of different organs and especially the cardiovascular system (STAUFFER et coll. 1957). With the improvement of image amplifiers, high speed cinefluorography has become available. A technique of precision motion analysis of high speed cinefluorograms of particulate contrast medium injected into the blood vessels of living animals has been developed in the radiology physiology laboratory of the Temple University Medical Center. This method has been used by several investigators for the study of blood flow in different vessels. LYNCH et coll. (1960) studied the flow patterns in the venae cavae in cats. GIMENEZ and collaborators (1961) reported on analysis of the flow patterns of particulate contrast material



Fig 1 Angiography by injection of Renografin 60 into the brachiocephalic artery of dog Right carotid left carotid and right vertebral arteries originate from the brachiocephalic artery

in blood vessels OHLSSON (1962) investigated the left heart and aortic blood flow in the dog using this technique PETERSEN studied the blood flow patterns of the distal thoracic and abdominal aorta in dogs We have used this method for the study of normal cervicocerebral flow in dogs for the establishment of a base line and this data will be applicable to studies of abnormal cervicocerebral flow

Methods A total of 44 mongrel dogs weighing from 5 5 to 23 kg were used The animals were anesthetized by the intravenous injection of 32 5 mg Pentobarbital sodium per kg In our first 14 experiments the right carotid and left vertebral arteries were studied separately in each animal in the last 33 experiments the carotid and vertebral arteries were studied simultaneously Two red Ödman catheters were introduced one in each femoral artery One catheter was advanced into the brachiocephalic artery from which originate the right carotid, the left carotid and the right vertebral arteries (*Fig 1*) The other catheter was used for the recording of blood pressure from the distal abdominal aorta The ECG heart sounds and blood pressure were constantly

FROM THE DEPARTMENTS OF RADIOLOGY (DIRECTOR PROF H M STAUFFER), PHYSIOLOGY (DIRECTOR PROF M J OPPENHEIMER), AND NEUROSURGERY (DIRECTOR PROF M SCOTT), TEMPLE UNIVERSITY MEDICAL CENTER, PHILADELPHIA, PENNSYLVANIA, U S A

HIGH SPEED CINEFLUOROGRAPHY OF CERVICOCEREBRAL BLOOD FLOW PATTERNS IN DOGS

by

A BONAKDARPOUR, P R LYNCH, I MURTAGH and H M STAUFFER

Since the introduction of cerebral angiography by MONIZ (1927) and rapid serial angiography by CURTIS (1949) considerable data has been collected on the roentgen anatomy of both intracranial and extracranial vessels Little radiologic physiologic information about the cervicocerebral circulation is available, however Since the invention of electronic x ray image intensifiers by COLTMAN (1918), the technique of cinefluorography (BONAKDARPOUR 1958) has been applied to investigate the physiology of different organs and especially the cardiovascular system (STAUFFER et coll 1957) With the improvement of image amplifiers, high speed cinefluorography has become available A technique of precision motion analysis of high speed cinefluorograms of particulate contrast medium injected into the blood vessels of living animals has been developed in the radiology physiology laboratory of the Temple University Medical Center This method has been used by several investigators for the study of blood flow in different vessels LYNCH et coll (1960) studied the flow patterns in the venae cavae in cats GIMENEZ and collaborators (1961) reported on analysis of the flow patterns of particulate contrast material

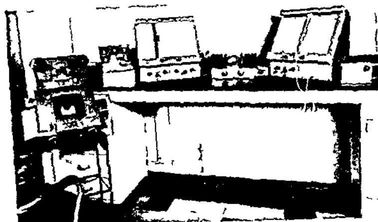


Fig 3 Data plotting equipment (from left to right) Vanguard motion analyzer cal brating control p nel X Y recorder (Electro Instruments Inc) *Philbrick fou ply analog* computer X Y recorder with curve follower (Elect o Instruments Inc) and power supply

Table

Dog No	Body weight	Angiographic vessel diameter	Electromagnetic flow rate (ml sec)		Electromagnetic flow velocities (cm/sec)		H S cinefluorography plotter velocities (cm/sec)		Associated artery
	(kg)	(mm)	Max	Min	Max	Min	Max	Min	
3?	17 7	8?	1 25	374	?1 ?	6 ?5	20 0	6 00	Vertebral
3	17 7	3 04	3 66	1 64	50 6	2? 8	5? 0*	30 0	Carotid
35	21 0	2 14	1 00	077	8 0	2 14	3? 0	? 60	Vertebral
35	21 0	3 34	4 97	? 60	56 6	29 7	56 0	15 0	Carotid
39	16 4	2 34	3 ?	467	74 5	10 9	70 0	6 68	Carotid
4?	15 6	? 27	3 ?3	1 33	79 8	3? 8	84 4	41.8	Carotid
4	15 6	2 00	1 16	217	36 9	6 ?	34	6 ?8	Vertebral
44	18 ?	? 50	5 9	1 34	120	27 4	91 0	29 2	Carotid
44	18	2 60	6 28	65	118	1? 3	80 5	19 9	Carotid
4	?3	50	4 84	834	98 8	17 0	84 6	?6 0	Carotid
46	21 3	46	4 41	1 33	93 0	28 0	140	38 2	Carotid

These figures represent the max mum velocity at the time of flow meter and high speed cinefluorography comparat stud es However maximu n carotid veloc ty was 90 cm/sec in this dog by th droplet technique at the beg nn ng of the study a d decreased to 5? cm/sec after a total in ectio of 2 3 ml of Eth od l b th *same technique*

Droplet time-displac ment curve was plotted near the area of the flow meter probe

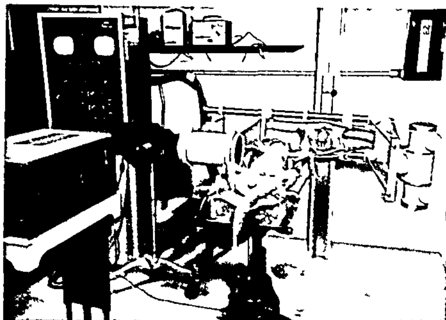


Fig 2 Equipment used for high speed cinefluorography high speed movie camera a six inch Philips image amplifier the electronics for medicine multichannel oscilloscope and recorder a Tektronix 502 dual beam oscilloscope and roentgen ray equipment

monitored on an electronics for-medicine multichannel recorder (Fig 2), and recorded when appropriate High speed cinefluorograms of the lateral view of the neck were made during the injection of 0 1 to 0 5 ml Ethiodol (iodized oil from E Fougera and Co Inc, Hicksville, New York) into the brachiocephalic artery With proper localization of the tip of the catheter in the brachiocephalic artery, the droplets of Ethiodol entered both carotids and the right vertebral artery The heart sounds and blood pressure were also recorded on the high speed movie film from a Tektronix 502 dual beam oscilloscope through a side lens of the high speed camera simultaneously with the fluoroscopic image (GIMENEZ et coll 1961, LYNCH et coll 1960 OHLSSON 1962) In each experiment, cineangiography of the cervicocerebral region was performed by the injection of Renografin 60 % (diatrizoate methylglucamine from E R Squibb & Sons, New York) for the measurement of vessel diameter

The high speed cinefluorograms were analyzed on a Vanguard motion analyzer (Fig 3) Time displacement curves of the droplets as well as blood pressure and heart sound recordings were plotted on an X Y plotter, and velocity and acceleration curves were then plotted from the time displacement curves by the use of a curve follower on an X Y plotter (GIMENEZ et coll 1961)

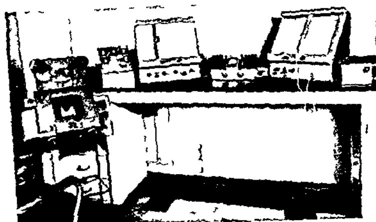


Fig 3 Data plotting equipment (from left to right) Vanguard motion analyzer calibrating control panel X Y recorder (Electro Instruments Inc) Philbrick four ply analog computer X Y recorder with curve follower (Electro Instruments Inc) and power supply

Table

Dog No	Body weight	Angiographic vessel diameter	Electromagnetic flow rate (ml sec)		Electromagnetic flow velocities (cm/sec)		H S cinefluorography plotter velocities (cm/sec)		Associated artery
	(kg)	(mm)	Max	Min	Max	Min	Max	Min	
3	17 7	2 87	1 25	374	21 2	6 25	20 0	6 00	Vertebral
3	17 7	3 04	3 66	1 64	50 6	22 8	52 0	30 0	Carotid
35	21 0	2 14	1 00	077	28 0	2 14	32 0	2 60	Vertebral
35	21 0	3 34	4 97	2 60	56 6	29 7	56 0	15 0	Carotid
39	16 4	2 34	3 2	467	74 5	10 9	70 0	6 68	Carotid
42	15 6	2 27	3 23	1 33	79 8	3 8	84 4	41.8	Carotid
4	15 6	2 00	1 16	217	36 9	6 9	34 2	6 28	Vertebral
44	18 2	2 50	5 92	1 34	120	77 4	91 0	79 2	Carotid
44	18 2	2 60	6 28	65	118	12 3	80 5	19 9	Carotid
45	3	2 50	4 84	834	98 8	17 0	84 6	76 0	Carotid
46	21 3	2 46	4 41	1 33	93 0	28 0	140*	38 2	Carotid

* These figures represent the maximum velocity at the time of flow meter and high speed cinefluorographic comparative studies However maximum carotid velocity was 90 cm/sec in this dog by the droplet technique at the beginning of the study and decreased to 52 cm/sec after a total injection of 2 3 ml of Ethiodol by the same technique

Droplet time displacement curve was plotted near the area of the flow meter probe

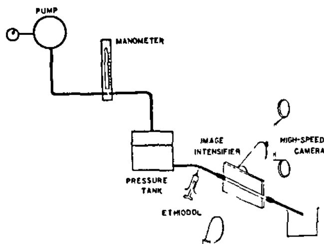


Fig 4 Schematics of procedure for hydrodynamic model experiments Fisher pressure vacuum single shaft air pump mercury manometer constant pressure reservoir calibrated collection beaker

When the velocities in the carotid artery were very high, the actual velocity had to be calculated from the time displacement curves using the formula $\overline{V} = \frac{dx}{dt}$ where x is the displacement of the droplet and t is the time (SEARS & ZEMANSKY 1963) Accuracy of the Vanguard motion analyzer technique for converting time displacement curves to velocity measurements decreases as the velocity increases Thus direct geometric measurements and calculations must be performed on high velocity droplet movement, so that there is no actual decrease in total accuracy of the method

Two experiments were performed with a dog in the prone position

In 11 experiments an electromagnetic flow meter was used for recording the blood flow Heart sounds (or blood pressure) and flow were simultaneously recorded on the high speed cinefluorograms during the injection of Ethiodol droplets (see Table)

For the further evaluation of this droplet technique, two series of hydrodynamic model experiments have been performed (Fig 4) using steady flow

In the first group of model experiments volume flow of water was measured through a siliconized polyethylene tube with an internal diameter of 1 778 mm under constant pressure By knowing the flow rate, the average velocities (SEARS & ZEMANSKY 1963) through the tube with and without injection of Ethiodol droplets were calculated In the second group of model experiments, the average velocity was measured by simultaneous volumetric and high speed cinefluorographic techniques

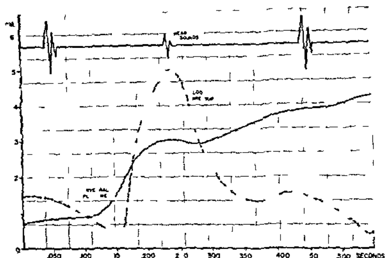


Fig 5 A time displacement recording of Ethiodol droplet movements from vertebral artery analysis The X axis represents the time in seconds and the Y axis the displacement in centimeters along the vessel

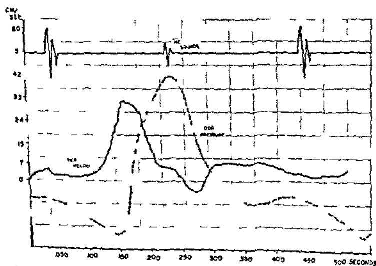


Fig 6 Velocity curve of vertebral artery droplets (same artery as shown in fig 5) Note the time lag of the rise of blood pressure in the distal aorta and velocity changes in the vertebral artery This is also demonstrated in fig 5 The X axis represents the time in seconds and the Y axis the velocity in centimeters per second along the vessel

Results

Comparative velocities The velocity of droplet flow in the common carotid is higher than that of the vertebral artery The maximum instantaneous (SEARS & ZEMANSKY 1963) systolic velocity in the common carotid artery ranged between 60 and 107 cm/sec The maximum instantaneous systolic velocity in the vertebral artery is always lower and varies from 30 to 60 % of that of the common carotid artery An example of a time displacement curve of droplet movement through the vertebral artery with simultaneous blood pressure and heart sound tracings is shown in Fig 5 The X axis reveals the time which has been calculated from the number of frames per second (each frame is 3 7 milliseconds) The Y axis shows the displacement of a droplet in centimeters after the correction for geometric magnification The velocity curve (maximum 32 cm/sec) recorded from the same vertebral artery is seen in Fig 6 The maximum instantaneous systolic velocity in the common carotid artery of this dog was 90 cm/sec A time displacement curve of droplet movements in the common carotid artery in another dog is shown in Fig 7 and the velocity curve (maximum 93 cm/sec) of the same common carotid artery in Fig 8

Fig 9 shows an example of the velocity curve of droplets passing through the vertebral artery as compared with a curve of blood flow passing through the same artery measured by an electromagnetic flow meter and recorded by high speed cinefluorography The flow curve has been analyzed by our technique and the corresponding velocities are shown on the ordinate at the level of the flow curve The two curves are quite similar in shape and amplitude the phase shift is due to the time rise of the flow meter Fig 10 illustrates the same curves with the common carotid velocity curve (by droplet technique) superimposed in order to show the comparative velocities by the techniques and also to compare the velocity of the common carotid and vertebral arteries

Model experiments In 34 separate model experiments the average velocity with Ethiodol was 174 cm/sec and without Ethiodol 189 cm/sec with an 8 % possible error In nine model experiments comparing the volumetric and high speed cinefluorographic methods the measurements confirmed the reliability of the latter technique with a difference in average velocities of only 17 cm/sec in a range of 137 cm/sec to 173 cm/sec

Back flow in the cervicocerebral vessels No back flow was observed within the common carotid artery of an anesthetized normotensive animal with the initial injection of the radiopaque particulate contrast medium However back flow was observed in the vertebral artery of normotensive animals

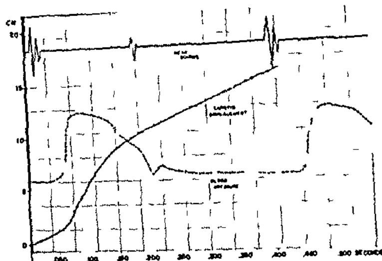


Fig 7 Time displacement recording of Ethiodol droplet analysis from the carotid artery The time lag has been corrected for as the blood pressure tracing by displacing the curve to the left The X axis represents the time in seconds and the Y axis the displacement in centimeters along the vessel

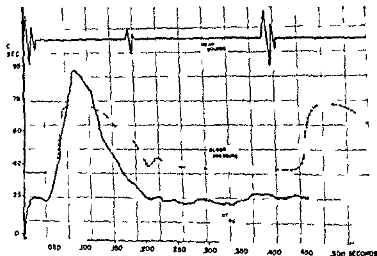


Fig 8 Velocity curve of the analyzed carotid artery droplets (same artery as shown in fig 7) The time lag has been again corrected for in the blood pressure tracing by shifting the curve to the left The X axis represents the time in seconds and the Y axis the velocity in centimeters per second along the vessel

Results

Comparative velocities. The velocity of droplet flow in the common carotid is higher than that of the vertebral artery. The maximum instantaneous (SEARS & ZEMANSKY 1963) *systolic velocity in the common carotid artery* ranged between 60 and 107 cm/sec. The maximum instantaneous systolic velocity in the vertebral artery is always lower and varies from 30 to 60 % of that of the common carotid artery. An example of a time displacement curve of droplet movement through the vertebral artery with simultaneous blood pressure and heart sound tracings is shown in Fig. 5. The X axis reveals the time which has been calculated from the number of frames per second (each frame is 3.7 milliseconds). The Y axis shows the displacement of a droplet in centimeters after the correction for geometric magnification. The velocity curve (maximum 32 cm/sec) recorded from the same vertebral artery is seen in Fig. 6. The maximum instantaneous systolic velocity in the common carotid artery of this dog was 90 cm/sec. A time displacement curve of droplet movements in the common carotid artery in another dog is shown in Fig. 7 and the velocity curve (maximum 93 cm/sec) of the same common carotid artery in Fig. 8.

Fig. 9 shows an example of the velocity curve of droplets passing through the vertebral artery as compared with a curve of blood flow passing through the same artery measured by an electromagnetic flow meter and recorded by high speed cinefluorography. The flow curve has been analyzed by our technique and the corresponding velocities are shown on the ordinate at the level of the flow curve. The two curves are quite similar in shape and amplitude; the phase shift is due to the time rise of the flow meter. Fig. 10 illustrates the same curves with the common carotid velocity curve (by *droplet technique*) superimposed in order to show the comparative velocities by the techniques and also to compare the velocity of the common carotid and vertebral arteries.

Model experiments. In 34 separate model experiments the average velocity with Ethiodol was 174 cm/sec and without Ethiodol 189 cm/sec with an 8 % possible error. In nine model experiments comparing the volumetric and high speed cinefluorographic methods the measurements confirmed the reliability of the latter technique with a difference in average velocities of only 17 cm/sec in a range of 137 cm/sec to 173 cm/sec.

Back flow in the cervicocerebral vessels. No back flow was observed within the common carotid artery of an anesthetized normotensive animal with the initial injection of the radiopaque particulate contrast medium. However back flow was observed in the vertebral artery of normotensive animals

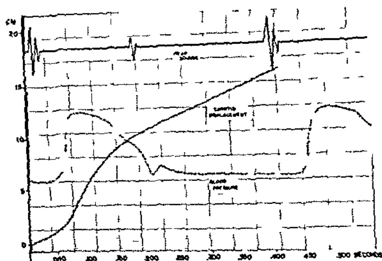


Fig 7 Time displacement recording of Fth odol droplet analysis from the carotid artery The time lag has been corrected for in the blood pressure tracing by displacing the curve to the left The X axis represents the time in seconds and the Y axis the displacement in centimeters along the vessel

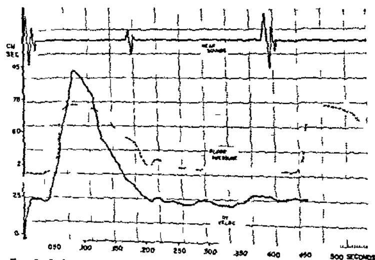


Fig 8 Velocity curve of the analyzed carotid artery droplets (same artery as shown in fig 7) The time lag has been again corrected for in the blood pressure tracing by shifting the curve to the left The X axis represents the time in seconds and the Y axis the velocity in centimeters per second along the vessel

Results

Comparative velocities The velocity of droplet flow in the common carotid is higher than that of the vertebral artery The maximum instantaneous (SEARS & ZEMANSKY 1963) systolic velocity in the common carotid artery ranged between 60 and 107 cm/sec The maximum instantaneous systolic velocity in the vertebral artery is always lower and varies from 30 to 60 % of that of the common carotid artery An example of a time displacement curve of droplet movement through the vertebral artery with simultaneous blood pressure and heart sound tracings is shown in Fig 5 The X axis reveals the time which has been calculated from the number of frames per second (each frame is 3 7 milliseconds) The Y axis shows the displacement of a droplet in centimeters after the correction for geometric magnification The velocity curve (maximum 32 cm/sec) recorded from the same vertebral artery is seen in Fig 6 The maximum instantaneous systolic velocity *in the common carotid* artery of this dog was 90 cm/sec A time displacement curve of droplet movements in the common carotid artery in another dog is shown in Fig 7 and the velocity curve (maximum 93 cm/sec) of the same common carotid artery in Fig 8

Fig 9 shows an example of the velocity curve of droplets passing through the vertebral artery as compared with a curve of blood flow passing through the same artery measured by an electromagnetic flow meter and recorded by *high speed cinefluorography* The *flow* curve has been analyzed by our technique and the corresponding velocities are shown on the ordinate at the level of the flow curve The two curves are quite similar in shape and amplitude the phase shift is due to the time rise of the flow meter Fig 10 illustrates the same curves with the common carotid velocity curve (by droplet technique) superimposed in order to show the comparative velocities by the techniques and also to compare the velocity of the common carotid and vertebral arteries

Model experiments In 34 separate model experiments the average velocity with Ethiodol was 174 cm/sec and without Ethiodol 189 cm/sec with an 8 % possible error *In nine model experiments comparing the volumetric* and high speed cinefluorographic methods the measurements confirmed the reliability of the latter technique with a difference in average velocities of only 17 cm/sec in a range of 137 cm/sec to 173 cm/sec

Back flow in the cervicocerebral vessels No back flow was observed within the common carotid artery of an anesthetized normotensive animal with the initial injection of the radiopaque particulate contrast medium However back flow was observed in the vertebral artery of normotensive animals

(377 ml/min) is lower than the highest mean flow rate of the human internal carotid artery (494 ml/min) as reported by HARDESTY et coll (1960)

Velocity of blood but not flow may change directly under the flow probe of the electromagnetic flow meter if the vessel size (external diameter) is larger than the internal diameter of the probe Variations in vessel size are impossible to control so that occasionally the velocity readings calculated from the electromagnetic flow meter may be too high for good comparative results (Table)

Acknowledgements

We gratefully acknowledge the interest and assistance in preparation of this paper of Mr Alfred Bove Mr Charles Zappelli Mr Albert Kaufman and Mr Vernon Castor Mr Artis Hall s photographic aid is also sincerely appreciated This investigation was supported (in part) by PHS Grants 5-T 1 HE 5362 HE 08886-01 HE 04757-04 and James Picker Foundation

SUMMARY

High speed cinefluorography of cervicocerebral blood flow patterns has been performed in 44 dogs Under normal physiologic conditions the dog s vertebral artery has a 30 to 60 slower movement of Ethiodol droplet than the common carotid artery Back flow in the vertebral artery was always seen while in the common carotid artery of the normotensive dog it d d not occur under our experimental conditions

ZUSAMMENFASSUNG

Bei 44 Hunden wurde Ultrarapidfilmung der Cervicocerebralen Blutzirkulation durch gefuhrt Unter normalen Bedingungen ist die Fortbewegung von Ethiodoltropfchen in der arteria vertebralis des Hundes 30—60 langsamer als in der arteria carotis communis Ein Ruckfluss war immer zu sehen in der Vertebralarterie wahrend ein solcher in der art ca otis des Hundes m t normalen Druckverhaltnissen bei unseren Versuchsbedingungen nicht auftrat

RÉSUMÉ

Les auteurs ont fait sur 44 chiens une cinéradiographie à grande vitesse des vaisseaux cervico-cérébraux Dans des conditions physiolo iques normales le mouvement des gouttelettes d Ethiodol est de 30 à 60 ° plus lent dans l artère vertébrale du chien que dans sa carotide primiti e Ils ont toujours constaté un reflux dans l artère vertébrale alors que dans leurs conditions d expérience il ne se produit jamais dans la carotide primitive chez les chiens normotendus

common carotid and the left vertebral artery were examined separately (in one half, the carotid was examined first and in the other, the vertebral). Then in the last 30 studies, they were examined simultaneously. In all of these examinations the droplet velocity was higher in the carotid than in the vertebral artery. To our knowledge this is the first comparative velocity study performed on these two vessels.

Since we have observed a change in droplet velocity after repeated injection of radiopaque oil, only the first few droplets have been used for plotting, to exclude the possibility of thrombosis of carotid or vertebral branches and changes in blood flow possibly thus induced. With repeated injection of oil droplet the blood velocity and consequently the blood flow decreases. The velocities obtained in three successive studies in the same dog are good examples (Figs 5, 6, 9 and 10). With the initial injection of oil droplets, the maximum common carotid droplet velocity was 90 cm/sec and that of the vertebral was 32 cm/sec (Figs 5 and 6). After injection of 1.1 ml of Ethiodol the maximum carotid velocity decreased to 73 cm/sec and that of the vertebral artery decreased to 20.0 cm/sec. After injection of 2.3 ml of Ethiodol the maximum common carotid droplet velocity further decreased to 52 cm/sec (Table).

On the basis of our hydrodynamic model experiments (Fig. 4), we make the assumption that in the range of internal vessel diameter, with which we are working, the droplet velocity is representative of the average axial blood velocity. Moreover, the comparative studies of droplet technique and electromagnetic flow meter measurements demonstrate the validity of this assumption (Table).

Presence or absence of back flow in the carotid artery has been discussed by many authors (INOUYE & KOSAKA 1959, KATZ & KOLIN 1938, MACHELLA 1936, MCDONALD 1960, SHIPLEY et coll. 1943). The normal presence of back flow in the carotid of anesthetized dogs has been emphasized by some authors and denied by MACHELLA and also by KATZ & KOLIN. SHIPLEY and collaborators have frequently observed back flow in the common carotid artery of dogs. INOUYE & KOSAKA have only rarely found a post systolic back flow in the carotid artery of dogs. On the basis of our experiments, which produce no trauma to the artery, back flow has not been observed in normal animals in the common carotid artery. However, back flow has been observed when the dog is in an abnormal state due either to hypotension or production of thrombosis by oil injection.

The maximum flow values in the Table correspond to P_1 and the minimum flow values to V_1, as has been described by INOUYE & KOSAKA.

It is noteworthy that the highest maximum flow in the common carotid artery of dogs, obtained by the electromagnetic flow meter in our experiments

FROM THE DEPARTMENT OF RADIOLOGY UCLA CENTER FOR THE HEALTH SCIENCES
LOS ANGELES CALIFORNIA U S A

THERMISTORS FOR MEASUREMENT OF CEREBRAL BLOOD FLOW

by

JAMES C BRILL AMOS NORMAN WILLIAM WEIDNER and WILLIAM HANAFEE

Thermistors are semiconductors which have a property of changing their resistance to the flow of electrical current inversely proportional to their temperature That is to say the colder a thermistor, the greater its resistance This property can be utilized for the measurement of blood flow using the hot wire anemometer principle (BRILL HANAFEE & NORMAN 1964 DELAUNOIS 1961)

Principle Thermistors were originally manufactured to measure temperature After appropriate calibrations have been made the thermistor is placed in an environment of unknown temperature Its resistance to a known electrical current can then be measured this resistance being dependent on the temperature of the new environment

In patients, body temperature can be accurately measured to within 0 02 to 0 03 C If the thermistor is inserted into the blood stream and an additional electrical current is made to flow through the instrument the thermistor being a resistor will become hotter than the blood Therefore, the colder blood flowing past the heated thermistor will take heat away from it or cool it changing its resistance

REFERENCES

BONAKDARPOUR A Principles and medical applications of electronic x ray image intensifiers Thesis Temple University School of Medicine Philadelphia (1958) 63

COLTMAN J W Fluoroscopic image brightening by electronic means Radiology 51 (1948) 359

CURTIS J B Rapid serial angiography Preliminary report J Neurol Neurosurg Psychiat 12 (1949) 167

GIMENEZ J L CARTER B L STEWART G H and LYNCH P R Flow pattern analysis of particulate contrast material in blood vessels Acta radiol 55 (1961) 350

HARDESTY W H ROBERTS B TOOLE J F and ROYSTER H P Studies of carotid artery blood flow in man New Engl J Med 263 (1960) 944

INOUYE A and KOSAKA H A study of flow patterns in carotid and femoral arteries of rabbits and dogs with the electromagnetic flow meter J Physiol 147 (1959) 209

KATZ L N and KOLIN A The flow of blood in the carotid artery of the dog under various circumstances as determined with the electromagnetic flow meter Amer J Physiol 122 (1938) 788

LYNCH P R CARTER B L GIMENEZ J and KRISCH R Venae Cavae flow pattern in cats as studied with high speed cinefluorographic technique Amer J Physiol 199 (1960) 1139

MACHELLA T E The velocity of blood flow in arteries in animals Amer J Physiol 115 (1936) 632

MC DONALD D A Blood flow in the arteries p 133 The Williams and Wilkins Company Baltimore 1960

MONIZ E L encephalographie arterielle son importance dans la localisation des tumeurs cerebrales Rev neurol 2 (1927) 72

OHLSSON N M Left heart and aortic blood flow in the dog Acta radiol Suppl 213 1962

PETERSEN K O Personal Communication Odense Denmark

SEARS F W and ZEMANSKY M W University Physics Third Edition Vol 1 p 67 and p 339 Addison Wesley Publishing Co Inc Reading Mass 1963

SHIPLEY R E GREGG D E and SCHROEDER E F An experimental study of flow patterns in various peripheral arteries Amer J Physiol 138 (1943) 718

STAUFFER H M OPPENHEIMER M J SOLOFF L A and STEWART G H Cardiac physiology revealed by the roentgen ray Amer J Roentgenol 78 (1957) 195

FROM THE DEPARTMENT OF RADIOLOGY UCLA CENTER FOR THE HEALTH SCIENCES
LOS ANGELES CALIFORNIA U S A

THERMISTORS FOR MEASUREMENT OF CEREBRAL BLOOD FLOW

by

JAMES C BRILL AMOS NORMAN WILLIAM WEIDNER and WILLIAM HANAFEE

Thermistors are semiconductors which have a property of changing their resistance to the flow of electrical current inversely proportional to their temperature That is to say the colder a thermistor the greater its resistance This property can be utilized for the measurement of blood flow using the hot wire anemometer principle (BRILL HANAFEE & NORMAN 1964 DELAUNOIS 1961)

Principle Thermistors were originally manufactured to measure temperature After appropriate calibrations have been made the thermistor is placed in an environment of unknown temperature Its resistance to a known electrical current can then be measured, this resistance being dependent on the tempera ture of the new environment

In patients body temperature can be accurately measured to within 0 02 to 0 03 C If the thermistor is inserted into the blood stream and an additional electrical current is made to flow through the instrument the thermistor, being a resistor will become hotter than the blood Therefore the colder blood flowing past the heated thermistor will take heat away from it or cool it, changing its resistance

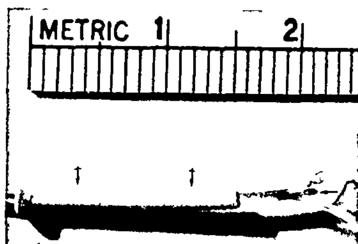
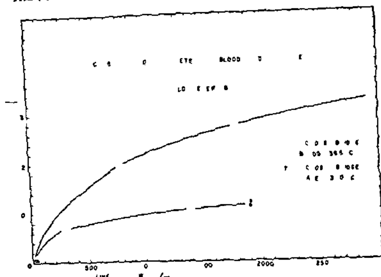


Fig 1 The three flanges of the distal end of the teflon catheter are molded to a flare by heating the teflon to 600 C for six seconds The thermistor 0 33 mm in diameter is then wired and mounted in the distal end of the catheter (→) A small length of P90 polyethylene (⟶) is placed over the teflon to facilitate insertion of the flow meter into the carotid catheter The polyethylene will cause the flanges of the flow meter to fold together

By measuring either the resistance of the thermistor or the amount of current necessary to keep it at a higher temperature than the blood, the linear velocity of the blood stream can be measured By accompanying these measurements with angiography, the diameter of the blood vessel, and hence its cross sectional area, can be measured from the roentgen films

Materials The actual construction of the flow meter is simple The 0 013 (Veco 34 A1) glass coated thermistor bead is mounted in a 100 cm long teflon tube 0 8 mm in diameter (Fig 1) The end of the teflon tube is split and splayed to center the thermistor in the vessel The leads of the thermistor consist of 0 001 platinum wire They are soldered to a No 40 copper wire which runs throughout the length of the teflon catheter The solder joints are insulated with belden wire enamel and the thermistor is bonded to the previously etched teflon tip with a special epoxy The mechanical properties of this epoxy allow flexion of the tip without loss of the thermistor or its connections

Electrically, the thermistor constitutes one arm of a Wheatstone bridge When the voltage across the bridge is very low, i e approximately 0 1 volt, the resistance of the thermistor is determined chiefly by ambient temperature But when the bridge voltage is increased, the thermistor begins to be heated by the extra current going through it As it is heated, its resistance drops The bridge is then balanced with the thermistors heated Anything that tends to



F g 2 R is the resistance of the therm sto in a l qu d that is not flowing ΔR is the cha ge in res stance that occurs d e to the cooling effect of e ther blood or water flowing past the heated thermistor The shift of the cal bratio i curve is apparently caused by the greater visco ity of blood

cool the thermistor, raises its resistance thus unbalancing the bridge The amount that the bridge is unbalanced is a measure of the linear velocity of flow to which the thermistor is exposed Calibration of the flow meter was done both in vitro in water and blood and in vivo in the dog The indifferent arms of the bridge are 500 Ω each The galvanometer is a Hewlett Packard 425A microvolt meterammeter The thermistor is about 3 500 Ω at 25 C and the variable arm of the bridge is a Leeds and Northrup 4 754 Decade resistance box

Calibration The thermistor is placed in a still water bath at 37 C Seven point seven volts (6 1 volt battery plus 1 6 volt battery) are placed across the bridge The variable arm of the bridge is adjusted so that the bridge is balanced Then various flows are circulated by the thermistor Each of these flows will cause the bridge to unbalance The bridge is rebalanced at that particular flow of interest The change in resistance i e $R_{fl\,w}$ minus $R_{\ fl\,w}$ is a measure of linear flow For the convenience of using a dimensionless variable we have plotted $\frac{R_f - R}{R}$ We have done the same sort of calibration circulating blood of 37 0 C past the flow meter (Fig 2)

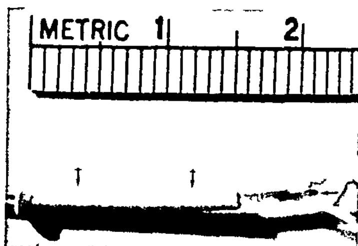


Fig 1 The three flanges of the distal end of the teflon catheter are molded to a flare by heating the teflon to 600 C for six seconds The thermistor 0 33 mm in diameter is then wired and mounted in the distal end of the catheter (→) A small length of P90 polyethylene (←→) is placed over the teflon to facilitate insertion of the flow meter into the carotid catheter The polyethylene will cause the flanges of the flow meter to fold together

By measuring either the resistance of the thermistor or the amount of current necessary to keep it at a higher temperature than the blood, the linear velocity of the blood stream can be measured By accompanying these measurements with angiography, the diameter of the blood vessel, and hence its cross sectional area, can be measured from the roentgen films

Materials The actual construction of the flow meter is simple The 0 013 (Veco 34 A1) glass coated thermistor bead is mounted in a 100 cm long teflon tube 0 8 mm in diameter (Fig 1) The end of the teflon tube is split and splayed to center the thermistor in the vessel The leads of the thermistor consist of 0 001 platinum wire They are soldered to a No 40 copper wire which runs throughout the length of the teflon catheter The solder joints are insulated with belden wire enamel and the thermistor is bonded to the previously etched teflon tip with a special epoxy The mechanical properties of this epoxy allow flexion of the tip without loss of the thermistor or its connections

Electrically, the thermistor constitutes one arm of a Wheatstone bridge When the voltage across the bridge is very low, i e approximately 0 1 volt, the resistance of the thermistor is determined chiefly by ambient temperature But when the bridge voltage is increased, the thermistor begins to be heated by the extra current going through it As it is heated, its resistance drops The bridge is then balanced with the thermistors heated Anything that tends to

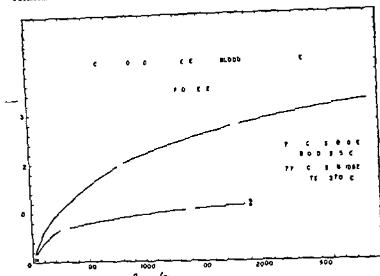


Fig 2 R is the resistance of the thermistor in a liquid that is not flowing ΔR is the change in resistance that occurs due to the cooling effect of either blood or water flowing past the heated thermistor The shift of the calibration curve is apparently caused by the greater viscosity of blood

cool the thermistor, raises its resistance thus unbalancing the bridge The amount that the bridge is unbalanced is a measure of the linear velocity of flow to which the thermistor is exposed Calibration of the flow meter was done both in vitro in water and blood and in vivo in the dog The indifferent arms of the bridge are 500 Ω each The galvanometer is a Hewlett Packard 425A microvolt meterammeter The thermistor is about 3 500 Ω at 25 C and the variable arm of the bridge is a Leeds and Northrup 4 754 Decade resistance box

Calibration The thermistor is placed in a still water bath at 37° C Seven point seven volts (6 1 volt battery plus 1 6 volt battery) are placed across the bridge The variable arm of the bridge is adjusted so that the bridge is balanced Then various flows are circulated by the thermistor Each of these flows will cause the bridge *to unbalance* The *bridge* is rebalanced at that particular flow of interest The change in resistance i e R_{flow} minus $R_{no\ flow}$ is a measure of linear flow For the convenience of using a dimensionless variable we have plotted $\frac{R_f - R}{R}$ We have done the same sort of calibration circulating blood of 37 0 C past the flow meter (Fig 2)

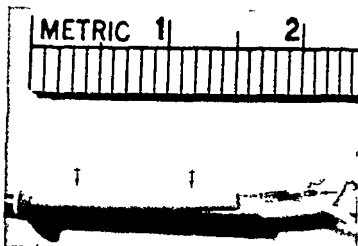


Fig 1 The three flanges of the distal end of the teflon catheter are molded to a flare by heating the teflon to 600 C for six seconds The thermistor 0 33 mm in diameter is then wired and mounted in the distal end of the catheter (→) A small length of P90 polyethylene (←→) is placed over the teflon to facilitate insertion of the flow meter into the carotid catheter The polyethylene will cause the flanges of the flow meter to fold together

By measuring either the resistance of the thermistor or the amount of current necessary to keep it at a higher temperature than the blood, the linear velocity of the blood stream can be measured By accompanying these measurements with angiography, the diameter of the blood vessel, and hence its cross sectional area, can be measured from the roentgen films

Materials The actual construction of the flow meter is simple The 0 013 (Veco 34 A1) glass coated thermistor bead is mounted in a 100 cm long teflon tube *0 8 mm in diameter (Fig 1) The end of the teflon tube is split* and splayed to center the thermistor in the vessel The leads of the thermistor consist of 0 001 platinum wire They are soldered to a No 40 copper wire which runs throughout the length of the teflon catheter The solder joints are insulated with belden wire enamel and the thermistor is bonded to the previously etched teflon tip with a special epoxy The mechanical properties of this epoxy allow flexion of the tip without loss of the thermistor or its connections

Electrically, the thermistor constitutes one arm of a Wheatstone bridge When the voltage across the bridge is very low i e approximately 0 1 volt, the resistance of the thermistor is determined chiefly by ambient temperature But when the bridge voltage is increased, the thermistor begins to be heated by the extra current going through it As it is heated its resistance drops The bridge is then balanced with the thermistors heated Anything that tends to

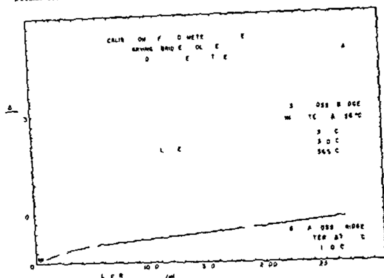


Fig 4 Cal b at ons were made at vary ng temperature of the water bath t) see if v riation in the patient s body temperature would interfere with flo measurements In g neral the d fferences are less than 5 per cent Similar observat ons were made n blood

measurement takes approximately four to five minutes A film is exposed of the vessel filled with contrast material The cross sectional area of the vessel is computed by first calculating the magnification factor from radiographed diameter of the catheter versus its actual measured diameter The internal diameter of the artery in question is measured by contrast material and then reduced by the magnification factor From our calibration we constructed a graph of $\frac{R_f - R_o}{R}$ versus linear velocity The measurement taken in the carotid artery is simply referred to the graph and the linear velocity is read off the graph thus

Linear velocity × cross sectional area of carotid artery = volume flow in the artery

Pitfalls

There are some anticipated questions to the use of this method

1 *Centering* In water no difference could be detected whether the device is centered or not with linear velocities up to 2 500 cm/min With blood in vivo centering does make a difference of 120 cm/min near the wall of the vessel

2 *Direction of flow* If the flow meter is heading into the water stream it

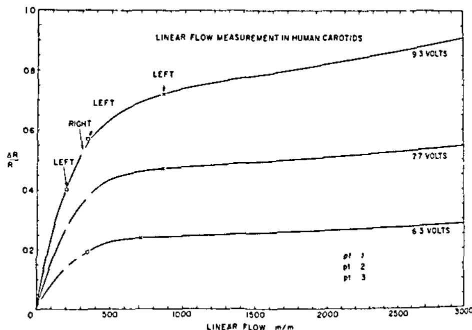


Fig 3 Three separate measurements are made in each artery with varying voltages across the thermistor The voltage changes cause a greater differential in temperature between blood and thermistor By measuring the cross sectional area of the internal carotid arteries in the neck the volume flow can be calculated by cross sectional area × linear flow The results were as follows

Patient I Left internal carotid artery 80 cc/min

□ Patient II Left internal carotid artery 18 cc/min

Patient III Right internal carotid artery 96 cc/min Left internal carotid artery 230 cc/min

Blood is more viscous than water Convection currents in blood are slower than in water For the same voltage across the bridge, the thermistor will be heated to a higher temperature in blood than in water Thus there are significant calibration differences between water and blood The flow meter is more sensitive for the same bridge voltage in blood than in water Sensitivity of the flow meter is determined by the difference in temperature of the thermistor and the flowing stream Obviously, the more voltage across the bridge, the hotter will be the thermistor, and thus the flow meter will be more sensitive

In our system we have taken $\frac{R_f - R_o}{R_o}$ as a measure of sensitivity

In practice, flow measurement is achieved by slipping the teflon catheter inside an angiographic catheter previously located in the carotid artery by percutaneous technique (Hanafee & Weidner 1963) The teflon catheter is fed through the angio catheter until its tip emerges in the blood stream The bridge voltage is applied and the bridge is balanced (Fig 3) The balance resistance is noted and the thermistor is withdrawn The whole process of

Fig 4 Calibrations were made at varying temperature of the water bath to see if variation in the patient's body temperature would interfere with flow measurements In general the differences are less than 5 per cent Similar observations were made in blood

measurement takes approximately four to five minutes A film is exposed of the vessel filled with contrast material The cross sectional area of the vessel is computed by first calculating the magnification factor from radiographed diameter of the catheter versus its actual measured diameter The internal diameter of the artery in question is measured by contrast material and then reduced by the magnification factor From our calibration we constructed a graph of $\frac{R_f - R}{R}$ versus linear velocity The measurement taken in the carotid artery is simply referred to the graph and the linear velocity is read off the graph thus

Linear velocity × cross sectional area of carotid artery = volume flow in the artery

Pitfalls

There are some anticipated questions to the use of this method

1 *Centering* In water no difference could be detected whether the device is centered or not with linear velocities up to 2 500 cm/min With blood in vivo centering does make a difference of 120 cm/min near the wall of the vessel

2 *Direction of flow* If the flow meter is heading into the water stream it

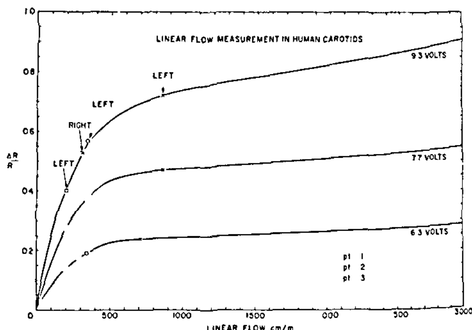


Fig 3 Three separate measurements are made in each artery with varying voltages across the thermistor The voltage changes cause a greater differential in temperature between blood and thermistor By measuring the cross sectional area of the internal carotid arteries in the neck the volume flow can be calculated by cross sectional area × linear flow The results were as follows
Patient I Left internal carotid artery 80 cc/min
□ Patient II Left internal carotid artery 18 cc/min
Patient III Right internal carotid artery 96 cc/min Left internal carotid artery 230 cc/min

Blood is more viscous than water Convection currents in blood are slower than in water For the same voltage across the bridge, the thermistor will be heated to a higher temperature in blood than in water Thus, there are significant calibration differences between water and blood The flow meter is more sensitive for the same bridge voltage in blood than in water Sensitivity of the flow meter is determined by the difference in temperature of the thermistor and the flowing stream Obviously the more voltage across the bridge, the hotter will be the thermistor, and thus the flow meter will be more sensitive

In our system we have taken $\frac{R_f - R_o}{R}$ as a measure of sensitivity

In practice, flow measurement is achieved by slipping the teflon catheter inside an angiographic catheter previously located in the carotid artery by percutaneous technique (HANAFEE & WEIDNER 1963) The teflon catheter is fed through the angio catheter until its tip emerges in the blood stream The bridge voltage is applied and the bridge is balanced (Fig 3) The balance resistance is noted and the thermistor is withdrawn The whole process of

Fig 4 Cal brat on were made at va ying temperature of the water bath to see if var ation in the patient s body temperature would i iterfere with flow m asu ements In general the d fferences are less than 5 per cent Sim lar observat ons were made n blood

measurement takes approximately four to five minutes A film is exposed of the vessel filled with contrast material The cross sectional area of the vessel is computed by first calculating the magnification factor from radiographed diameter of the catheter versus its actual measured diameter The internal diameter of the artery in question is measured by contrast material and then reduced by the magnification factor From our calibration, we constructed a graph of $\frac{R_f - R}{R}$ versus linear velocity The measurement taken in the carotid artery is simply referred to the graph and the linear velocity is read off the graph thus

Linear velocity $\times$ cross sectional area of carotid artery = volume flow in the artery

Pitfalls

There are some anticipated questions to the use of this method

1 *Centering* In water no difference could be detected whether the device is centered or not with linear velocities up to 2 500 cm/min With blood in vivo centering does make a difference of 120 cm/min near the wall of the vessel

2 *Direction of flow* If the flow meter is heading into the water stream it

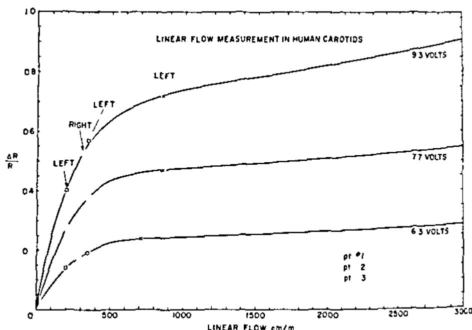


Fig 3 Three separate measurements are made in each artery with varying voltages across the thermistor The voltage changes cause a greater differential in temperature between blood and thermistor By measuring the cross sectional area of the internal carotid arteries in the neck the volume flow can be calculated by cross sectional area × linear flow The results were as follows
Patient I Left internal carotid artery 80 cc/min
□ *Patient II* Left internal carotid artery 48 cc/min
× Patient III Right internal carotid artery 96 cc/min Left internal carotid artery 230 cc/min

Blood is more viscous than water Convection currents in blood are slower than in water For the same voltage across the bridge, the thermistor will be heated to a higher temperature in blood than in water Thus, there are significant calibration differences between water and blood The flow meter is more sensitive for the same bridge voltage in blood than in water Sensitivity of the flow meter is determined by the difference in temperature of the thermistor and the flowing stream Obviously, the more voltage across the bridge, the hotter will be the thermistor, and thus the flow meter will be more sensitive In our system we have taken $\frac{R_f - R_o}{R_o}$ as a measure of sensitivity

In practice, flow measurement is achieved by slipping the teflon catheter inside an angiographic catheter previously located in the carotid artery by percutaneous technique (HANAFEE & WEIDNER 1963) The teflon catheter is fed through the angio catheter until its tip emerges in the blood stream The bridge voltage is applied and the bridge is balanced (Fig 3) The balance resistance is noted and the thermistor is withdrawn The whole process of

Fig 4 Calibrations were made at varying temperature of the water bath to see if variation in the patient's body temperature would interfere with flow measurements In general the differences are less than 5 per cent Similar observations were made in blood

measurement takes approximately four to five minutes A film is exposed of the vessel filled with contrast material The cross sectional area of the vessel is computed by first calculating the magnification factor from radiographed diameter of the catheter versus its actual measured diameter The internal diameter of the artery in question is measured by contrast material and then reduced by the magnification factor From our calibration we constructed a graph of $\frac{R_f - R}{R}$ versus linear velocity The measurement taken in the carotid artery is simply referred to the graph and the linear velocity is read off the graph thus

Linear velocity × cross sectional area of carotid artery = volume flow in the artery

Pitfalls

There are some anticipated questions to the use of this method

1 *Centering* In water no difference could be detected whether the device is centered or not with linear velocities up to 2 500 cm/min With blood *in vivo* centering does make a difference of 120 cm/min near the wall of the vessel

2 *Direction of flow* If the flow meter is heading into the water stream it

will record 5 % more linear velocity at 2 500 cm/min than it will if the stream is coming from behind.

3. *Stability and drift.* If thermistors are used only for temperature measurement, drift is guaranteed by the manufacturer at less than 0.1 per cent. However, by running a current of 8 to 10 milliamperes through the thermistor to produce milliamperes through the thermistor to produce self heating, several changes seem to occur. Its resistance varies from day to day at specific temperatures. In addition, calibration curves tend to change in configuration. One explanation of these changes may be based on shifting of oxygen molecules bound to the metallic oxides of thermistor beads.

4. *Thermistor care.* Care must be taken not to overheat the thermistor, as this will change its physical properties. Sudden surges of current cause an 'avalanching effect' *which may melt the small electrical leads.*

5. *Clotting and coagulation of the blood.* The thermistor has been heated 50 C above the temperature of still oxalated blood without causing coagulation. Although the thermistor is hot, the actual heat transfer is very small. Clotting dangers may be minimized by (1) siliconizing the catheter tip, and (2) avoiding prolonged measurement.

6. *Change in body temperature.* According to our data, we can tolerate a shift in the temperature of the bath or of the blood of as much as 1.0° C without any detectable effect. Our calibration is accurate from 36.5° C to 37.5° C (Fig. 4). Such gross fluctuations are not likely to occur during the short measuring interval.

7. *Arterial spasm and turbulent flow.* Localized spasm or stenosis can cause marked variations in velocity throughout the length of the carotid artery. Since the thermistors are not radiopaque their precise location cannot be determined.

Conclusions

Although thermistors offer a new technique for non operative measurement of blood flow, several handicaps prevent their widespread use. The drift and lack of stability of thermistors means that frequent calibrations are essential. In our hands, one week is the longest period of time one calibration has remained in use. This also varies considerably between individual thermistor beads. Calibrations must be made in blood and an average time of five hours has been required for completing our curves.

We hope to overcome some of these problems in the near future by use of higher inherent resistance thermistor beads to yield greater stability. In addition improved electronics may change thermistors from a valuable research tool to a daily clinical measurement.

Acknowledgement

This paper was written with the technical assistance of Mr Jon M Shinno

SUMMARY

Thermistors offer an additional means of measuring volume blood flow Our instrument can conveniently be inserted at the time of carotid angiography if the catheter technique is used

ZUSAMMENFASSUNG

Thermistore sind ein Hilfmittel zur Messung des Blutvolumens Unser Instrument kann bei Anwendung der Kathetertechnik mit Vorteil wahrend der Carotis Angiographis angebracht werden

RÉSUMÉ

Les thermistors offrent un nouveau moyen de mesurer le débit sanguin Si on utilise le cathétérisme notre instrument peut être introduit au cours de l angiographie carotidienne

REFERENCES

BRILL J HANAFEE W and NORMAN A A flowmeter for use in angiographic studies Radiology 82 (1964) 133

DELAUNOIS A L Continuous measurement of blood flow and cardiac output by means of a Cournard catheter equipped with thermistors Arch int Pharmacodyn 134 (1961) 245

HANAFEE W and WEIDNER W Selective carotid angiography Radiology 81 (1963) 589

will record 5 % more linear velocity at 2 500 cm/min than it will if the stream is coming from behind

3 *Stability and drift* If thermistors are used only for temperature measurement, drift is guaranteed by the manufacturer at less than 0 1 per cent However, by running a current of 8 to 10 milliamperes through the thermistor to produce milliamperes through the thermistor to produce self heating, several changes seem to occur Its resistance varies from day to day at specific temperatures In addition, calibration curves tend to change in configuration One explanation of these changes may be based on shifting of oxygen molecules bound to the metallic oxides of thermistor beads

4 *Thermistor care* Care must be taken not to overheat the thermistor, as this will change its physical properties Sudden surges of current cause an 'avalanching effect' which may melt the small electrical leads

5 *Clotting and coagulation of the blood* The thermistor has been heated 50° C above the temperature of still oxalated blood without causing coagulation Although the thermistor is hot, the actual heat transfer is very small Clotting dangers may be minimized by (1) siliconizing the catheter tip, and (2) avoiding prolonged measurement

6 *Change in body temperature* According to our data, we can tolerate a shift in the temperature of the bath or of the blood of as much as 1 0° C without any detectable effect Our calibration is accurate from 36 5° C to 37 5° C (Fig 4) Such gross fluctuations are not likely to occur during the short measuring interval

7 *Arterial spasm and turbulent flow* Localized spasm or stenosis can cause marked variations in velocity throughout the length of the carotid artery Since the thermistors are not radiopaque their precise location cannot be determined

Conclusions

Although thermistors offer a new technique for non operative measurement of blood flow, several handicaps prevent their widespread use The drift and lack of stability of thermistors means that frequent calibrations are essential In our hands, one week is the longest period of time one calibration has remained in use This also varies considerably between individual thermistor beads Calibrations must be made in blood and an average time of five hours has been required for completing our curves

We hope to overcome some of these problems in the near future by use of higher inherent resistance thermistor beads to yield greater stability In addition improved electronics may change thermistors from a valuable research tool to a daily clinical measurement

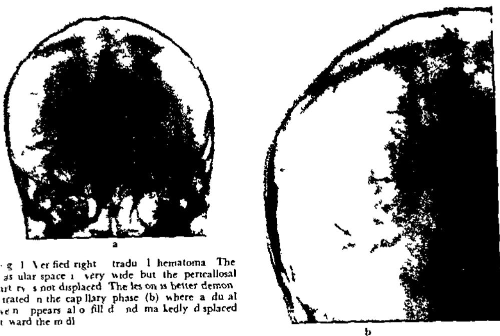


Fig 1 Verified right extradural hematoma The avascular space is very wide but the pericallosal artery is not displaced The lesion is better demonstrated in the capillary phase (b) where a dural vein appears also filled and markedly displaced toward the midl

We now wish to emphasize another diagnostic element the discrepancy between the width of the avascular space and the displacement of the midline blood vessels i e the pericallosal artery and internal cerebral vein

This radiographic sign was observed by CRONQVIST & KOHLER (1963) in 9 out of 25 extradural hematomas (3 temporal lateral 5 parietal and 1 occipital) In other cases such as in 5 temporal basal hematomas the avascular space was not clearly visible but the displacement of the pericallosal artery and of the internal cerebral vein was less than that of the Sylvian vessels The avascular space was absent in 3 out of 4 frontal hematomas while in the case of an occipital effusion it was possible to demonstrate it only by means of an oblique projection Of the 25 patients 7 had multiple intracranial traumatic lesions it is not always clear which data refer to the simple rather than to the complicated hematomas

Material Our material consists of 21 acute traumatic extradural hematomas which were verified at surgery of these 16 were simple and 5 were associated with other lesions two with cerebral laceration, two with cerebral laceration and subdural hematoma and one with subdural hematoma All cases were diagnosed preoperatively as extracerebral expanding processes Among the

FROM THE DEPARTMENT OF NEURORADIOLOGY (DIRECTOR PROF G RUGGIERO),
OSPEDALE MAGGIORE, BOLOGNA, ITALY

ANGIOGRAPHIC TECHNIQUE AND DIAGNOSIS IN BRAIN LACERATIONS AND EXTRADURAL HEMATOMAS

by

PIETRO DETTORI and GIOVANNI RUGGIERO

For a number of years our group has devoted particular attention to neuro traumatology and to radiological diagnosis of acute head injuries (RUGGIERO 1962) The present study deals with two problems 1) the correct diagnosis of extracerebral hematomas, and 2) a particular angiographic technique in cases of acute head injuries, which has proved of special interest in brain lacerations

The most important criteria in the differential diagnosis of extracerebral effusions were presented in a preliminary note at the Tenth International Congress of Radiology in Montreal in 1962 (RUGGIERO et coll 1964) They are summarized below

	Subdural hematomas	Extradural hematomas
Frontal view	Hemispheral outlining of the avascular space smooth and regular Absence of displacement of branches of the middle meningeal artery	Hemispheral outlining of the avascular space irregular and indented Displacement toward the midline of the branches of the middle meningeal artery
Lateral view	Normal	Signs of space occupying lesion

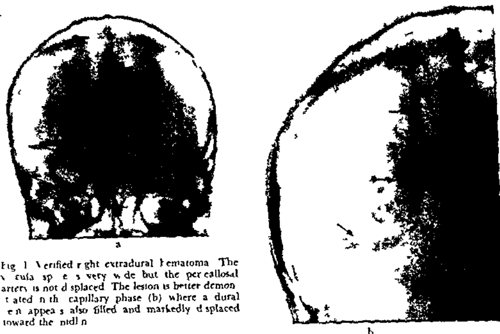


Fig 1 Verified right extradural hematoma The vascular space is very wide but the pericallosal artery is not displaced The lesion is better demonstrated in the capillary phase (b) where a dural vein appears also filled and markedly displaced toward the midline

We now wish to emphasize another diagnostic element the discrepancy between the width of the avascular space and the displacement of the *midline* blood vessels i e the pericallosal artery and internal cerebral vein

This radiographic sign was observed by CRONQVIST & KOHLER (1963) *in 9 out of* 25 extradural hematomas (3 temporal lateral 5 parietal and 1 occipital) In other cases *such as in 5 temporal basal* hematomas the avascular space was *not clearly visible but* the displacement of the pericallosal artery and of the internal cerebral vein *was less than* that of the Sylvian vessels The avascular space was absent *in 3 out of 4* frontal hematomas while in the case of an occipital effusion it was possible to demonstrate it only by means of an oblique projection Of the 25 patients 7 had multiple intracranial traumatic lesions it is not always clear which data refer to the simple rather than to the complicated hematomas

Material Our material consists of 21 acute traumatic extradural hematomas which were verified at surgery of these 16 were simple and 5 were associated with other lesions two with cerebral laceration two with cerebral laceration and subdural hematoma and one with subdural hematoma All cases were diagnosed preoperatively as extracerebral expanding processes Among the

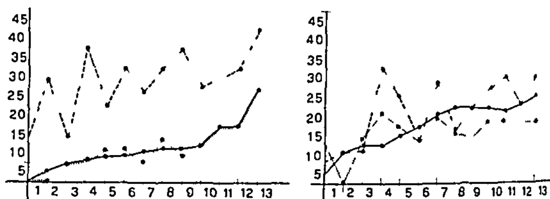


Fig. 2. Ratio between width of avascular space (interrupted line) and displacement of the pericallosal artery (solid line) and internal cerebral vein (dotted line) in mm. Subdural hematomas on right, extradural on left.

simple extradural hematomas 13 were diagnosed as such, while in the remaining 3 an unsatisfactory technique did not allow a good evaluation of the radiograms.

Discussion

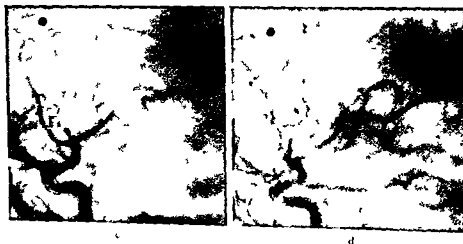
In our series all *simple extracerebral hematomas* showed a displacement of the pericallosal artery and the internal cerebral vein which was always less than the width of the avascular area (Fig. 1). For a better evaluation of this sign, data from 13 extradural hematomas have been compared with those from a similar number of subdural lesions (Fig. 2).

In cases of extracerebral hematomas complicated by other lesions such as contusions or lacerations the relationship is necessarily altered. It is obvious that an intracerebral lesion which is expanding will tend to reduce the avascular space due to an associated extracerebral hematoma, while it will increase the displacement of the midline vessels toward the opposite side; for this reason the discrepancy between the width of the avascular space is of diagnostic value only in those extracerebral hematomas which are not associated with other lesions.

When we are confronted with *cerebral lacerations*, especially if small, comparison between right and left angiographies may be necessary (Fig. 3). There are two possibilities: 1) puncture of both carotids prior to the taking of any radiograms; this will allow bilateral angiographies in the same projection, but arterial puncture of the contralateral carotid may prove to have been unnecessary; 2) after the first angiography, puncture of the contralateral carotid without moving the head, thus performing the second angiography under identical radiographic conditions. This is the technique we have



a b



c d

Fig 3 Small ight te npo al lace at on The smallest d fference in the aspect of the r ght (a) and left (b) i ddle cer bral rteries and the r ght (c) and left (d) carot d s phons can be appreciated since th p oje tions re d ntical

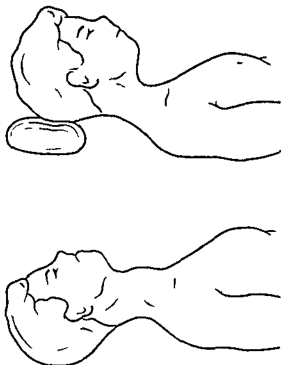


Fig 4 Ideal position for puncturing the internal or common carotid artery (bottom) Position suitable in cases of cranial trauma (above)

adopted, in spite of its difficulties If the patient is uncooperative, general anesthesia is necessary, one must learn to puncture the artery with the patient's head slightly flexed (Fig 4), this being far from the hyperextended position For this reason we always try to puncture carotids without extending the patient's head, even in non traumatic cases The flexed head technique is also useful in patients with intracranial tumors in whom hyperextension of the head, by raising venous tension, can increase intracranial pressure

SUMMARY

The ratio between the displacement of the pericallosal artery and internal cerebral vein and the width of the vascular space in extracerebral hematomas is analyzed The value of this sign in differentiating extra and subdural hematomas is emphasized The technique of carotid puncture in head injuries is discussed a position with the head flexed being recommended

ZUSAMMENFASSUNG

Bei extracerebralen Hämatomen wird das Verhältnis zwischen der Dislokation der Art pericallosa und Vena cerebr int und der Weite des avaskulären Spatiums analysiert. Der Wert dieses Zeichens für die Differenzierung von extra und subduralen Hämatomen wird hervorgehoben. Die Technik der Carotidspunktion bei Schädelverletzungen wird besprochen, wobei eine Flexionsstellung des Schädels empfohlen wird.

RÉSUMÉ

Dans le but de préciser le diagnostic des hématomes extraduraux les auteurs analysent le rapport entre ampleur de l'espace avasculaire et déplacement de l'artère péricallose et veine cérébrale interne. En discutant la technique angiographique les auteurs proposent dans les cas de traumatisme cranien de ponctionner l'artère carotide interne ou primitive dans une position tête fléchie.

REFERENCES

CRONQVIST S and KOHLER R Angiography in epidural haematomas Acta radiol 1 (1963) 42

RUGGIERO G Il quadro radiologico del cranio acuto Rapporto al Congresso della Società dei Neurologi Ospedalieri Roma 1962

— CALABRO A METZGER J and SIMON J Arteriography of the external carotid artery Acta radiol 1 (1963) 395

— LEIGHTON R S DETTORI P and COLUMELLA F Acute cranial trauma Acta radiol 2 (1964) 487

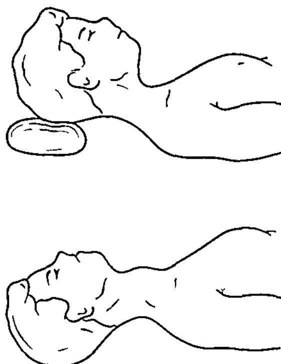


Fig 4 Ideal position for puncturing the internal or common carotid artery (bottom) Position suitable in cases of cranial trauma (above)

adopted, in spite of its difficulties If the patient is uncooperative, general anesthesia is necessary, one must learn to puncture the artery with the patient's head slightly flexed (Fig 4), this being far from the hyperextended position For this reason we always try to puncture carotids without extending the patient's head, even in non traumatic cases The flexed head technique is also useful in patients with intracranial tumors in whom hyperextension of the head, by raising venous tension, can increase intracranial pressure

SUMMARY

The ratio between the displacement of the pericallosal artery and internal cerebral vein and the width of the vascular space in extracerebral hematomas is analyzed The value of this sign in differentiating extra and subdural hematomas is emphasized The technique of carotid puncture in head injuries is discussed a position with the head flexed being recommened

ZUSAMMENFASSUNG

Bei extracerebralen Hamatomen wird das Verhaltnis zwischen der Dislokation der Art pericallosa und Vena cerebri int. und der Weite des avaskularen Spatiums analysiert. Der Wert dieses Zeichens fur die Differenzierung von extra-und subduralen Hamatomen wird hervorgehoben. Die Technik der Carotispunktion bei Schadelverletzungen wird besprochen wobei eine Flexionsstellung des Schadels empfohlen wird.

RÉSUMÉ

Dans le but de preciser le diagnostic des hématomes extraduraux les auteurs analysent le rapport entre ampleur de l espace avasculaire et deplacement de l artere pericalleuse et veine cerébrale interne. En discutant la technique angiographique les auteurs proposent dans les cas de traumatisme cranien de ponctionner l artere carotide interne ou primitive dans une position tete fléchie

REFERENCES

CRONQVIST S and KOHLER R Angiography in epidural haematomas Acta rad 1 (1963) 42

RUGGIERO G Il quadro rad ologico del cranio acuto Rapporto al Congresso della Societa dei Neurologi Ospedalieri Roma 1962

— CALABRO A METZEGER J and SIMON J Arteriography of the external carotid artery Acta radiol 1 (1963) 395

— LEIGHTON R S DETTORI P and COLUMELLA F Acute cranial trauma Acta radiol 2 (1964) 487

SERVICE DE NEURORADIOLOGIE (PROF. H. FISCHGOLD) ET CLINIQUE NEUROCHIRURGICALE (PROF. M. DAVID) DE L'HOPITAL DE LA PITIÉ, PARIS, FRANCE

LA SOUSTRACTION APPLIQUÉE A L'ÉTUDE ANGIOGRAPHIQUE DES LÉSIONS DE LA FOSSE POSTÉRIEURE

par

D. DILENGE et J. METZGER

La soustraction que nous utilisons comme complément de l'angiographie depuis 1961 est devenue ces derniers temps une technique de routine.

Les avantages en sont particulièrement nets pour l'angiographie vertébrale et ceci non seulement pour l'identification des vaisseaux veineux et artériels, mais aussi dans l'appréciation de la vascularisation des lésions néo formées de la fosse postérieure.

L'étude de 32 lésions de la fosse postérieure prouve que grâce à une soustraction correcte, les vaisseaux sans la superposition osseuse particulièrement gênante au niveau des rochers (tant en projection de face que de profil) se laissent reconnaître avec netteté sur tout leur trajet, les vaisseaux néo formés peuvent ainsi se détacher nettement du fond osseux atténué.

Parmi ces 32 lésions, on trouve 9 neurinomes de l'acoustique, 5 méningiomes (3 de l'angle, 1 du clivus et 1 de la convexité cérébelleuse), 3 angioréticulomes, 7 angiomes, un anévrysme du tronc basilaire, 2 cas de traumatisme.

Pour chaque type de lésion nous avons cherché à dégager les détails angio



Fig. 1 Angioréticulome cérebelleux La projection antéro-postérieure retrouve grace à la soustraction tout son intérêt même en angiographie vertébrale elle dégage en plus des détails peu visibles sur les cliches conventionnels d autres mal rendus par la projection de profil Dans ce cas il est impossible par exemple d individualiser sur l angiogramme de profil (a) tous les noyaux opaques objectivés sur l angiogramme de face (b)

graphiques que la soustraction a permis d obtenir en plus par rapport a l angiographie conventionnelle

Soulignons tout d abord l interet que nous avons porte à la projection de face dans les cas ou il etait possible de pratiquer la soustraction pour les deux projections Les images d opacification pathologique dans plusieurs de ces cas etaient peu visibles sur l angiogramme de profil mais nous les avons retrouvees parfois tres nettement sur l angiogramme de face (Fig 1)

La raison en est que sur l angiogramme de profil, la superposition des deux lobes cerébelleux au temps capillaire produit une opacite du parenchyme dans laquelle l image pathologique peut se perdre completement L opacité cérebelleuse ainsi devient significative dans la fosse postérieure et il est facile d en apprecier l importance dans les cas ou l ombre cerebelleuse n apparait que d un cote seulement

Nous n avons trouvé aucune opacification particuliere dans les 9 cas de neurinome de l acoustique Sur les angiogrammes de face dans 3 d entre eux cependant nous avons pu noter un vaisseau péritumoral avec une disposition en vaisseaux bordants des branches artérielles peri tumorales (Fig 2)

Dans un seul cas la tumeur dont les limites paraissaient nettement definies par un de ces vaisseaux bordants apparaissait moins transparente que les tissus avoisinants

Dans les cas de meningiome la soustraction a permis de verifier le manque



Fig. 2. Neurinome de l'acoustique à droite. Les vaisseaux avoisinants sont disposés en vaisseaux bordants.



Fig. 3. Gros méningiome de la convexité du cervelet. La branche méningée de l'artère vertébrale est particulièrement développée et à ses dépens semblent s'être formés des néo-vaisseaux.

de vascularisation pathologique par l'artère vertébrale lorsque la tumeur était située dans la partie antérieure de la fosse postérieure.

Dans le seul cas où la tumeur était située dans la partie postérieure de la fosse postérieure, nous avons constaté une vascularisation pathologique aux dépens d'une branche méningée postérieure (Fig. 3).

Parmi les tumeurs intracérébelleuses, nous avons pu mettre en évidence des vaisseaux néo-formés dans un médulloblastome et dans une métastase. Dans le médulloblastome, on nota tout d'abord une hypertrophie de l'artère cérébelleuse moyenne gauche et ensuite des vaisseaux néo-formés. L'aspect



Fig. 4. a) Aucune image certaine de vascularisation pathologique n'est mise en évidence sur l'angiogramme conventionnel. b) La soustraction nous permit de noter la présence de vaisseaux faisant partie d'une hypervascularisation pathologique au niveau de la lésion.



Fig. 5. Ces deux clichés qui ont été obtenus avec une projection qu'on ne peut utiliser qu'avec la soustraction objectivent *bien les contours* latéraux et postéro-inférieurs des lobes cérébelleux.

vasculaire de la métastase *pouvait* s'identifier avec celui des autres métastases notées au niveau des hémisphères cérébraux.

L'étude des tumeurs et des malformations *vasculaires* est particulièrement favorisée par la soustraction puisque *nous avons* pu dégager facilement les pédicules afférents. La soustraction a *été particulièrement* utile dans les cas où ces pédicules ne s'identifiaient *pas avec une artère* cérébelleuse et où ils étaient *en partie* masqués par la *superposition* de l'os occipital; dans un cas d'angiome de la tente, le pédicule était constitué par une branche de la méningée postérieure.

Dans un cas d'angiome cérébelleux, le *malade fut* opéré avec le diagnostic de tumeur cérébelleuse à la suite d'un examen pneumographique et iodo

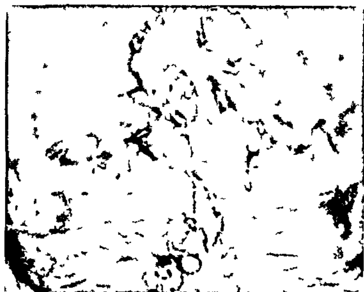


Fig. 2. Neurinome de l'acoustique à droite. Les vaisseaux avoisinants sont disposés en vaisseaux bordants.



Fig. 3. Gros méningiome de la convexité du cervelet. La branche méningée de l'artère vertébrale est particulièrement développée et à ses dépens semblent s'être formés des néo vaisseaux.

de vascularisation pathologique par l'artère vertébrale lorsque la tumeur était située dans la partie antérieure de la fosse postérieure.

Dans le seul cas où la tumeur était située dans la partie postérieure de la fosse postérieure, nous avons constaté une vascularisation pathologique aux dépens d'une branche méningée postérieure (Fig. 3).

Parmi les tumeurs intracérébelleuses, nous avons pu mettre en évidence des vaisseaux néo formés dans un médulloblastome et dans une métastase. Dans le médulloblastome, on nota tout d'abord une hypertrophie de l'artère cérébelleuse moyenne gauche et ensuite des vaisseaux néo formés. L'aspect



F g 4 a) Auc m image certaine de vascularisat on patholog qu n est mise en évidence sur l ang o gran me o vent onnel b) La soustraction nous permit de noter la presence de vaisseaux faisant p rt e d une hyper ascularisation pathologiqu au niveat de la les on



Fig 5 Les deux clichés qu ont ét obtenus avec un p ojection qu on n peut ut liser qu a ec s u tract on object vent bi n les contours latéraux *et postero-* nferieurs des lobes cérébelleux

vascul ure de la met istase pouvait s identifier avec celui des autres metastases notees au niveau des hemispheres cerebraux

L etude des tumeurs et des malformations vasculaires est particulierement favorisee par la soustraction puisque nous avons pu degager facilement les pedicules afferents La soustraction a ete particulierement utile dans les cas ou ces pedicules ne s identifiaient pas avec une artere cerebelleuse et ou ils etaient en partie masques par la superposition de l os occipital, dans un cas d angiome de la tente le pedicule etait constitue par une branche de la menin gee posterieure

Dans un cas d angiome cérebelleux le malade fut opére avec le diagnostic de tumeur cerebelleuse a la suite d un examen pneumographique et iodo

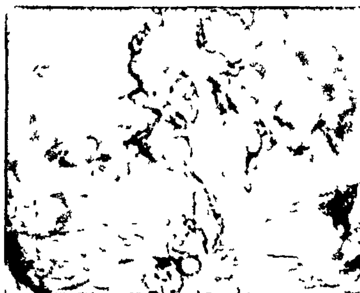


Fig. 2. Neurinome de l'acoustique à droite. Les vaisseaux avoisinants sont disposés en vaisseaux bordants.



Fig. 3. Gros méningiome de la convexité du cervelet. La branche méningée de l'artère vertébrale est *particulièrement développée et à ses dépens semblent s'être formés des néo-vaisseaux.*

de vascularisation pathologique par l'artère vertébrale lorsque la tumeur était située dans la partie antérieure de la fosse postérieure.

Dans le seul cas où la tumeur était située dans la partie postérieure de la fosse postérieure, nous avons constaté une vascularisation pathologique aux dépens d'une branche méningée postérieure (Fig. 3).

Parmi les tumeurs intracérébelleuses, nous avons pu mettre en évidence des vaisseaux néo-formés dans un médulloblastome et dans une métastase. Dans le médulloblastome, on nota tout d'abord une hypertrophie de l'artère cérébelleuse moyenne gauche et ensuite des vaisseaux néo-formés. L'aspect

SERVICE DE RADIOLOGIE (PROF AGRÉGÉ J LEFEBVRE) HOPITAL DES ENFANTS MALADES ET SERVICE DE NEURO CHIRURGIE (PROF AGRÉGÉ R HOUDART) HOPITAL LARIBOISIERE PARIS FRANCE

EXPLORATION ANGIOGRAPHIQUE DES MALFORMATIONS VASCULAIRES DE LA MOELLE EPINIÈRE

par

R DJINDJIAN C FAURÉ R HOUDART et J LEFEBVRE

Les malformations vasculaires du systeme nerveux ont connu des classifica tions multiples qui sont essentiellement fondées sur des criteres neuro patho logiques leurs details importent moins que la distinction fondamentale due a CUSHING & BAILEY (7) entre tumeurs et malformations Seules ces dernieres seront envisagées ici dans leurs localisations médullaires

Au niveau de l encéphale l angiographie cérébrale devenue examen de routine a rapidement prouve sa valeur en tant que méthode d étude physio logique C est elle qui a rendu compréhensible les lesions vasculaires malforma tives les scindant en deux grands groupes anévrismes artériels et anevrismes arterio veineux

En objectivant le shunt artério veineux l angiographie et elle seule a per mis une approche satisfaisante des angiomes cérébraux et parallèlement, l élaboration d une tactique chirurgicale dont le succes prouve l efficacite

En matiere de malformations vasculaires medullaires la période anatomo clinique se prolonge encore La nomenclature proposee par WYBURN MASSON (36) en 1943 demeure la plus couramment utilisée dans les publications de ces

ventriculographique. L'angiographie vertébrale qui fut malheureusement pratiquée du côté opposé, nous était apparue négative sur les clichés conventionnels, sans aucune néoformation vasculaire particulière. La soustraction pratiquée après l'intervention a permis de découvrir malgré tout, plusieurs vaisseaux de la néo-formation (Fig. 4).

Dans les deux cas de traumatisme, la symptomatologie était en faveur d'une *lésion de la fosse postérieure et l'angiographie avec et sans soustraction fut* négative. Dans l'un de ces cas qui fut opéré on trouva un hématome intra-cérébelleux.

A ce propos, nous désirons souligner, que grâce à la soustraction il devient possible de découvrir d'éventuels décollements corticaux. Le cervelet, opacifié lui-même et bordé par les veines, repoussé par l'hématome, doit laisser libre de tout vaisseau l'espace de décollement (Fig. 5).

RÉSUMÉ

Les auteurs ont appliqué la soustraction à l'angiographie vertébrale de face et de profil dans 32 lésions de la fosse postérieure. Ils soulignent l'intérêt de cette technique pour l'étude de la vascularisation des méningiomes, des tumeurs malignes et des malformations vasculaires et pour le diagnostic des hématomes extra-cérébelleux.

SUMMARY

The subtraction method was used for vertebral angiography, for both antero-posterior and lateral films, in 32 lesions of the posterior fossa. The value of the technique is stressed for the study of the vessels in meningiomas, malignant tumours and vascular malformations, as well as for the diagnosis of extra-cerebellar hematomas.

ZUSAMMENFASSUNG

Die Subtraktion wurde in 32 expansiven Prozessen der hinteren Schädelgrube in frontalen und lateralen Vertebral-Angiogrammen angewendet. Es wird auf dem Wert der Methode für die Beurteilung der Blutversorgung der Meningiomen, der bösartigen Tumoren und der Gefässmissbildungen und für die Diagnose der extracerebellaren Hämatomen hingewiesen.

BIBLIOGRAPHIE

DAVID, M., DILENGE, D. et BRIHAYE, J. Les progrès réalisés dans la connaissance des malformations artério-veineuses cérébrales. Importance des techniques angiographiques. *Acta chir. belg., 9 (1963), 961.*

DILENGE, D., DAVID, M., SIMON, J. et MORICE, J. Valeur sémiologique des branches méningées de l'artère carotide interne et de l'artère vertébrale. Neurochirurgie 10 (1964), 265.

FISCHGOLD, H. et DILENGE, D. La plus petite artère visible par angiographie orbitaire. Livre jubil. L. Van Bogaert. Acta med. belg., Bruxelles (1962), 280.

ZIEDSES DES PLANTES, B. G. Subtraktion. G. Thieme, Stuttgart, 1961.



Fig 2 Cas 2 Aortographie par voie fémorale Face centrée sur le cou Soustraction L angiome s projette sur C4—C5 Pédicules multiples issus des vertébrales droite et gauche et des branches du tronc thyro-bi-scapulaire des deux côtés

de la methode de soustraction de ZIEDZES DES PLANTES (37) ce procede photographique ameliore la qualite des images et en facilite la lecture

Les observations suivantes illustrent les possibilites de ces explorations angio graphiques

Observations

Cas 1 Femme de 22 ans Début clinique à 12 ans Actuellement triplégie spasmodique avec troubles urinaires Les clichés simples du rachis et la myélographie lipiodolée font porter le diagnostic d angiome médullaire en C4—C6 Une phlébographie rachidienne est négative

Artériographie par ponction de la sous-clavière gauche Au temps artériel (Fig 1a) se dessine un angiome de forme ovalaire alimenté par deux pédicules afférents inférieurs nés de la vertébrale comme l ont montré des clichés de profil et par un pédicule latéral venant de l *artere* cervicale ascendante Sur les temps plus tardifs s injectent précocement des veines de drainage et les plexus extra rachidiens gauches Une nouvelle injection avec centrage sur la *partie haute* du cou montre que les arteres spinales antérieure et postérieure fournissent des afférences au pole supérieur de la malformation (Fig 1 b et c)

Cas 2 Homme de 21 ans Début brutal par douleurs cervico-scapulaires céphalées vomissements hypoacousie et amaurose transitoires *Dans les antécédents* épisode analogue a l age de 12 ans A l exam n un syndrome méningé franc un signe de Babinski unilatéral gauche La ponction lombaire retire un liquide franchement hémorragique

Les angiographies carotidiennes droite et gauche sont négatives L angiographie vertébrale

ventriculographique. L'angiographie vertébrale qui fut malheureusement pratiquée du coté opposé, nous était apparue négative sur les clichés conventionnels, sans aucune néoformation vasculaire particulière. La soustraction pratiquée après l'intervention a permis de découvrir malgré tout, plusieurs vaisseaux de la néo formation (Fig. 4).

Dans les deux cas de traumatisme, la symptomatologie était en faveur d'une lésion de la fosse postérieure et l'angiographie avec et sans soustraction fut négative. Dans l'un de ces cas qui fut opéré on trouva un hématome intra cérébelleux.

A ce propos, nous désirons souligner, que grâce à la soustraction il devient possible de découvrir d'éventuels décollements corticaux. Le cervelet, opacifié lui même et bordé par les veines, repoussé par l'hématome, doit laisser libre de tout vaisseau l'espace de décollement (Fig. 5).

RÉSUMÉ

Les auteurs ont appliqué la soustraction à l'angiographie vertébrale de face et de profil dans 32 lésions de la fosse postérieure. Ils soulignent l'intérêt de cette technique pour l'étude de la vascularisation des méningiomes, des tumeurs malignes et des malformations vasculaires et pour le diagnostic des hématomes extra cérébelleux.

SUMMARY

The subtraction method was used for vertebral angiography for both antero posterior and lateral films in 32 lesions of the posterior fossa. The value of the technique is stressed for the study of the vessels in meningiomas, malignant tumours and vascular malformation as well as for the diagnosis of extra cerebellar hematomas.

ZUSAMMENFASSUNG

Die Subtraktion wurde in 32 expansiven Prozessen der hinteren Schädelgrube in frontalen und lateralen Vertebral Angiogrammen angewendet. Es wird auf dem Wert der Methode für die Beurteilung der Blutversorgung der Meningiomen, der bösartigen Tumoren und der Gefässmissbildungen und für die Diagnose der extracerebellaren Hämatomen hingewiesen.

BIBLIOGRAPHIE

DAVID M., DILENGE D. et BRIHAYE J. Les progrès réalisés dans la connaissance des malformations artério-veineuses cérébrales. Importance des techniques angiographiques. Acta chir. belg. 9 (1963) 961.

DILENGE D., DAVID M., SIMON J. et MORICE J. Valeur sémiologique des branches méningées de l'artère carotide interne et de l'artère vertébrale. Neurochirurgie 10 (1964) 265.

FISCHGOLD H. et DILENGE D. La plus petite artère visible par angiographie orbitaire. Livre jubil. L. Van Bogaert. Acta med. belg. Bruxelles (1962) 280.

ZIEDSES DES PLANTES B. G. Subtraktion. G. Thieme Stuttgart 1961.

SERVICE DE RADIOLOGIE (PROF AGRÉGÉ J LEFEBVRE), HOPITAL DES ENFANTS MALADES ET SERVICE DE NEURO CHIRURGIE (PROF AGRÉGÉ R HOUDART) HÔPITAL LARIBOISIERE PARIS FRANCE

EXPLORATION ANGIOGRAPHIQUE DES MALFORMATIONS VASCULAIRES DE LA MOELLE EPINIÈRE

par

R DJINDJIAN C FAURE R HOUDART et J LEFEBVRE

Les malformations vasculaires du systeme nerveux ont connu des classifications multiples qui sont essentiellement fondees sur des criteres neuro pathologiques leurs details importent moins que la distinction fondamentale due a CUSHING & BAILEY (7) entre tumeurs et malformations Seules ces dernieres seront envisagees ici dans leurs localisations medullaires

Au niveau de l encephale l angiographie cerebrale devenue examen de *routine* a rapidement prouvé sa valeur en tant que méthode d etude physiologique C est elle qui a rendu comprehensible les lesions vasculaires malformatives les *scindant* en deux grands groupes anevrismes artériels et anevrismes arterio veineux

En objectivant le shunt arterio veineux l angiographie et elle seule a permis une approche satisfaisante des angiomes cérébraux et parallelement l élaboration d une tactique chirurgicale dont le succes prouve l efficacite

En matiere de malformations vasculaires medullaires la periode anatomo clinique se prolonge encore La nomenclature proposée par WYBURN MASSON (36) en 1943 demeure la plus couramment utilisée dans les publications de ces

vingt dernières années. L'anévrisme racémeux veineux, l'anévrisme artério-veineux, les anomalies artérielles y sont différenciés sur des critères statiques, visuels ou anatomiques. Cette hétérogénéité paraît bien paradoxale en comparaison avec l'énorme prédominance des malformations artério-veineuses décelées par l'angiographie au niveau du cerveau. C'est pourquoi bien des auteurs ont récemment mis en doute la valeur de cette classification.

Le peu d'intérêt accordé aux études angiographiques nous paraît significatif de la force des idées reçues. HENSON & CROFT (18) dans leur publication de 1956, rapportent les premiers, à notre connaissance, le cas d'un anévrisme artério-veineux cervical mis en évidence par angiographie cérébrale dès mai 1953.

RAND & RAND (30) en 1960 commentent dans leur cas n° 2 l'intérêt et les risques de l'aortographie qui leur a permis d'objectiver en 1954 un angiome de la jonction dorso-lombaire. Leurs réflexions ne devaient trouver que peu d'échos puisque seuls DI CHIRO (8) en 1957, HOOK & LIDVALL (19) en 1958, et MORRIS (28) en 1960 utilisaient l'angiographie vertébrale pour étudier quelques cas isolés cervicaux d'angioréticulome ou de malformations vasculaires. Depuis 1961, date à laquelle nous avons étudié notre premier cas d'angiome médullaire, nous avons entrepris une étude angiographique systématique de tous les cas de malformations vasculaires médullaires qui nous ont été confiés. C'est le résultat de cette enquête que nous rapportons ici.

Nous serons volontairement brefs sur les données étiologiques et cliniques et soulignerons seulement quelques points : 1) l'atteinte prédominante du sexe masculin (8♂, 4♀), 2) la précocité des troubles, fait qui va à l'encontre de l'extrême rareté de la mise en évidence de ces malformations chez l'enfant, souvent affirmée par la littérature, 3) la constance des manifestations douloureuses qui représentent souvent le premier signe et qui demeurent longtemps isolées, 4) l'évolution par poussées plus ou moins complètement régressives, ce mode évolutif a été noté neuf fois sur douze, 5) la relative rareté des hémorragies sous-arachnoïdiennes (trois cas sur douze) est conforme aux données de la littérature, contrairement à ce que l'on pourrait penser ces hémorragies sont loin de faciliter le diagnostic, bien au contraire elles orientent souvent à tort vers une malformation cérébrale et font pratiquer en premier lieu des angiographies carotidiennes et vertébrales.

Les examens radiologiques classiques apportent souvent au diagnostic des arguments d'appoint ou de certitude.

Sur les clichés simples, l'élargissement du canal rachidien, l'augmentation des distances inter-pédiculaires, l'amincissement d'un ou plusieurs pédicules traduisent la présence d'un processus expansif intra-rachidien, ces modifications ont été observées essentiellement dans les localisations cervicales ou

cervico dorsales (2 cas sur 4) et dorsales (4 cas sur 4), plus rarement dans la region du cone terminal Une scoliose a ete notée dans 2 cas

La presence de calcifications rapportée une fois par WALKER (35), l association classique mais rare d un angiome vertebral sont des arguments de présomption en faveur d un angiome medullaire Mentionnons aussi la dilatation de la crosse de la veine azygos que nous avons retrouvée à posteriori sur les clichés simples de deux de nos malades a la lumiere des angiographies, dans des localisations cervico dorsale et dorsale

La myelographie aux contrastes positifs constituait jusqu à maintenant le moyen diagnostique le plus sur un blocage plus ou moins net de la bille opaque revelait la lesion dont la nature angiomateuse était prouvée par la presence de moulages vasculaires GUILLAIN & ALAJOUANINE (16) furent les premiers a decrire cette image en 1925 cependant elle n est pas constante meme en s aidant de precautions techniques et en utilisant un index opaque volumineux comme le conseille LOMBARDI & MIGLIAVACCA (27) il est des cas ou la myélographie revele un blocage isolé, la nature vasculaire de l obstacle etant decouverte au moment de l intervention Outre ses risques, sur lesquels nous ne nous etendrons pas la myelographie a l inconvénient de ne pas apporter de preuve formelle Des images de moulages vasculaires sont quelquefois observées au voisinage de certaines tumeurs intra rachidiennes avec stase veineuse on les voit egalement dans certaines coarctations aortiques

Ces imperfections de la myélographie lipiodolée sont mentionnées par beaucoup d auteurs dont certains tels SVIEN & BAKER (33) deplorent l impossibilite d utiliser pour la moelle les procedes angiographiques si fructueux pour l etude de l encephale Ces auteurs rapportent les échecs de leurs tentatives de phlebographie intra rachidienne faites dans le but d *opacifier ces malformations* Precison que pour notre part dans les trois cas ou nous avons utilise la phlébographie nous n avons pas pu injecter l angiome

C est en fonction des connaissances actuelles de la vascularisation *medullaire* et par assimilation avec les malformations arterio veineuses *cerebrales* que nous avons decidé dans un cas examine *par phlebographie* en 1961 de faire *dans le meme* temps operatoire profitant de l anesthésie generale une aortographie Le *succes* de cet examen nous a incité a poursuivre nos efforts dans *ce sens*

En fonction de notre expérience et compte tenu des conditions anatomiques d irrigation artérielle de la *moelle, les* explorations arteriographiques de cet organe doivent se faire de la maniere suivante

1) pour le segment cervical ou cervico dorsal *il faut opacifier* separement *les* deux arteres sous clavières et la *portion terminale* de la crosse aortique Du cote droit la sous claviere est *examinée* par ponction directe du coté



Fig 1 Cas 1 Angiographie sous clavière gauche a) Temps artériel Cliché de face centré sur l angiome Soustraction La malformation reçoit deux afférences l une née de la vertébrale l autre de la cervicale ascendante b) and c) Temps artériel Clichés de face et de profil centrés sur la partie haute du cou Soustraction Les artères spinales antérieure et postérieure fournissent des afférences au pole supérieur de la malformation

gauche elle est étudiée soit par ponction directe, soit mieux par cathétérisme rétrograde a partir de la fémorale, l aorte est opacifiée par cathétérisme rétrograde

2) pour le segment dorsal, nous faisons une aortographie thoracique, pour la région du cone terminal une aortographie thoraco abdominale Là encore, nous utilisons le cathétérisme femoral rétrograde, selon le procedé de Seldinger (32)

La qualité des renseignements fournis par ces angiographies dépend du soin apporté à la realisation des examens Nombre d impératifs techniques sont à respecter, bien connus des radiologistes habitués aux examens angiographiques Nous soulignerons seulement quelques points essentiels l intéret de l'anesthésie générale, la nécessité d une étude seriographique de durée assez longue (12 a 15 secondes), la nécessite d'explorer pour un territoire donné, tout les vaisseaux susceptibles d apporter des afférences à la malformation, l'intéret primordial



Fig 2 Cas 2 Aortographie par voie femorale Face centrée sur le cou Soustraction L angiome se projette sur C4—C5 Pédicules multiples issus des vertébrales droite et gauche et des branches du tronc thyro-bi scapulaire des deux cotés

de la methode de soustraction de ZIEDZES DES PLANTES (37), ce procedé photographique améliore la qualite des images et en facilite la lecture

Les observations suivantes illustrent les possibilites de ces explorations angio graphiques

Observations

Cas 1 Femme de 22 ans Début clinique a 12 ans Actuellement triplégie spasmodique avec troubles urinaires Les clichés simples du rachis et la myélographie lipiodolée font porter le diagnostic d angiome médullaire en C4—C6 Une phlébographie rachidienne est négative

Artériographie par ponction de la sous-claviere gauche Au temps artériel (Fig 1a) se dessine un angiome de forme ovalaire alimenté par deux pédicules afférents inférieurs nés de la vertébrale comme l ont montré des clichés de profil et par un pédicule latéral venant de l artère cervicale ascendante Sur les temps plus tardifs s injectent précocement des veines de drainage et les plexus extra rachidiens gauches Une nouvelle injection avec centrage sur la partie haute du cou montre que les arteres spinales antérieure et postérieure fournissent des afférences au pole supérieur de la malformation (Fig 1 b et c)

Cas 2 Homme de 21 ans Debut brutal par douleurs cervico-scapulaires céphalées vomissements hypoacousie et amaurose transitoires Dans les antécédents épisode analogue à l age de 12 ans A l examen un syndrome méningé franc un signe de Babinski unilatéral gauche La ponction lombaire retire un liquide franchement hémorragique

Les angiographies carotidiennes droite et gauche sont négatives L angiographie vertébrale



Fig 1 Cas I Angiographie sous clavière gauche a) Temps artériel Cliché de face centré sur l angiome Soustraction La malformation reçoit deux afférences l une née de la vertébrale l autre de la cervicale ascendante b) and c) Temps artériel Clichés de face et de profil centrés sur la partie haute du cou Soustraction Les artères spinales antérieure et postérieure fournissent des afférences au pole supérieur de la malformation

gauche elle est étudiée soit par ponction directe, soit mieux par cathétérisme rétrograde à partir de la femorale, l aorte est opacifiée par cathétérisme re trograde

2) pour le segment dorsal, nous faisons une aortographie thoracique, pour la région du cone terminal une aortographie thoraco abdominale La encore, nous utilisons le cathétérisme femoral rétrograde, selon le procéde de SEL DINGER (32)

La qualité des renseignements fournis par ces angiographies dépend du soin apporté à la réalisation des examens Nombre d impératifs techniques sont a respecter, bien connus des radiologistes habitués aux examens angiographiques Nous soulignerons seulement quelques points essentiels l intéret de l anesthésie générale, la nécessité d une étude sériographique de durée assez longue (12 à 15 secondes), la nécessité d explorer pour un territoire donné tout les vaisseaux susceptibles d apporter des afferences à la malformation, l'intéret primordial



Fig 3 Cas 6 Aortographie par voie femorale cathéter au niveau de D6 a) Temps artériel précoce Soustraction de face Deux afferences nourrissent cet angiome l une volumineuse venue de la 6ème intercostale droite (→) l autre accessoire née de la 2ème intercostale droite (⟶) b) Temps artériel tardif Soustraction La masse angiomateuse est très étendue déjà s opacifient les premières efferences c) Temps veineux Soustraction Extrême étendue et complexité des efferences veineuses qui aboutissent aux plexus extra rachidiens et a la veine azygos dilatée

supérieur de l angiome Du coté droit une afférence principale née en regard de D5 fournit en regard du 3 espace inter costal une branche volumineuse à destinée intrarachidienne qui atteint l angiome à sa partie moyenne Une afférence accessoire provient de la 4 artere inter costale droite Le shunt artério-veineux est authentifié par l apparition précoce de veines efferentes essentiellement inférieures sur les temps tardifs on peut suivre l une de ces veines volumineuses dans le canal rachidien jusqu au niveau du rachis dorsal inférieur

Cet adolescent meurt quelques semaines plus tard à la suite d une nouvelle hémorragie méningée La vérification anatomique apporte plusieurs précisions intéressantes elle confirme l existence d un angiome vertébral en D4 soupçonné sur les radiographies simples du rachis elle découvre un angiome au niveau du foie et elle permet de pratiquer des coupes sériées de la moelle qui montrent l absence d hémorragie à l intérieur de la moelle la situation essentiellement extra médullaire et postérieure des vaisseaux anormaux dont la pénétration dans la moelle se limitait à la région dorsale supérieure l existence de thromboses disséminées à plusieurs endroits de la malformation

Cas 5 Garçon de 6 ans Apparition brutale en fin de journée de douleurs thoraciques droites puis dans la nuit de céphalées En moins de 48 heures se constitue un syndrome de Brown Sequard La paralysie du membre inférieur droit est totale l hypoesthésie gauche remonte jusqu à D4 on note un signe de Babinski bilatéral une abolition des réflexes cutanés abdominaux et crémastériens une rétention d urine

centrée sur le crane fait discuter un possible anévrisme du tronc basilaire mais un examen plus approfondi de la région cervicale haute montre sur ce film les artères spinales dilatées

Myélographie le lipiodol injecté par voie lombaire marque un temps d arrêt en C6 puis moule des images vasculaires typiques en C5 et C4

On fait une nouvelle angiographie vertébrale droite par ponction sous clavière centrée sur la région cervicale On obtient ainsi l image d une malformation vasculaire nourrie par deux afférences artérielles l une supérieure née de la vertébrale l autre inférieure provenant d une branche de la sous clavière probablement la cervicale ascendante A un temps plus tardif de gros vaisseaux veineux s étendent tout le long du rachis cervical

Une aortographie par voie fémorale permet de controler l artere sous claviere gauche (Fig 2) On découvre ainsi deux nouvelles afférences l une née de la cervicale ascendante va au pole inferieur de l angiome l autre plus fine pénètre le rachis en C4—C5 Aucune afference plus bas située n est trouvée A un temps plus tardif le drainage veineux apparait à partir des deux poles de la malformation Ce patient a subi plusieurs interventions successives destinées à exclure cet angiome du courant circulatoire Le traitement chirurgical n est pas encore terminé mais déjà nos controles angiographiques ont montré l efficacité des ligatures artérielles celles ci n ont été suivies d aucun incident d ordre neurologique médullaire

Cas 3 Femme de 34 ans Depuis l age de 7 ans installation par poussées successives entrecoupées de rémissions d une paraplégie complète avec troubles sphinctériens et douleurs dorsales hautes

La myélographie lipiodolée montre un arret en D1 avec moulage de vaisseaux anormaux

Les angiographies cervicales par ponction directe des artères sous clavières droite et gauche ont montré que seule l artère sous clavière gauche irriguait l angiome L étude angiographique est reprise quelques jours plus tard par cathétérisme rétrograde de l artère fémorale Le cathéter est d abord placé dans l artère vertébrale gauche A un temps artériel une volumineuse afference née de l artère vertébrale aborde l angiome par son pole supérieur A un temps ultérieur s opacifie précocement une volumineuse veine de drainage Le cathéter est ensuite placé dans l aorte thoracique Une nouvelle sériographie objective une volumineuse afférence inférieure née de la 7 inter costale gauche et se divisant en deux branches qui abordent le pole inférieur de l angiome

Le traitement chirurgical par temps successifs visant à exclure la malformation est actuellement en cours il est bien supporté mais nous ne pouvons encore en fournir les résultats

Cas 4 Garçon de 16 ans Une hémorragie méningée ouvre la scène clinique à l age de 12 ans deux nouveaux épisodes hémorragiques surviennent un an plus tard Une étude angiographique carotidienne bilatérale et vertébro basilaire est négative L année suivante de nouvelles hémorragies méningées se produisent Des signes neurologiques s installent les uns orientant vers une pathologie médullaire haute les autres traduisant une hypertension intra cranienne

La myélographie lipiodolée montre un ralentissement de la bille opaque en D6 puis des images de moulages vasculaires en D3

Une angiographie médullaire est réalisée par voie fémorale rétrograde Une première injection dans l artère sous clavière gauche montre que ce vaisseau n irrigue pas l angiome On place ensuite le cathéter dans l aorte en regard de D5 On opacifie ainsi une malformation vasculaire dont les afférences artérielles sont complexes Du coté gauche une grosse artère née de l aorte monte sur le flanc gauche du rachis jusqu au 2 espace inter costal elle fournit à ce niveau une branche dorso spinale qui pénètre le rachis en D2—D3 et aboutit au pôle



Fig 5 Cas 8 Aortographie a) Temps artériel tardif Soustraction Opacification d énormes dilatations veineuses en grappe emplissant le canal medullaire Deux pédicules afférents l inferieur volumineux naissant de la dorso-spinale dilatée de D9 (→) formant une double courbure à concavité gauche le supérieur de petit calibre issu de la dorso-spinale de D8 (⟶) ascendante puis formant une boucle a concavite inférieure qui l emmene au pole supérieur de l angiome b) Temps veineux Soustraction Le pole inférieur de l angiome fournit deux pédicules veineux volumineux de grande étendue l un médian sinueux l'autre lateralisé se jettant dans les plexus veineux latéro-vertébraux

diagnostic d angiome est porté par la myélographie Un bilan angiographique nous est demandé avant une intervention chirurgicale sur la scoliose

L aortographie thoracique est faite par voie fémorale Des le début de l injection s opacifie un volumineux angiome avec shunt artério-veineux précoce nourri par une afference principale venue de la 6 inter costale droite et par une afférence accessoire née de la 2 inter costale Une seconde plus tard la masse angiomateuse parait très étendue et s opacifient déja les premieres efférences veineuses

A un temps tardif (Fig 3c) les efférences veineuses sont opacifiées étendues et complexes elles aboutissent au plexus extra rachidien et a la veine azygos dilatée

Le traitement chirurgical visant à exclure par ligatures successives cet angiome est actuellement en cours

Cas 7 Fillette de 3 ans 1/2 Installation en 24 heures d une paraplégie flasque complète avec rétention d urine et anesthésie totale dont la limite supérieure remonte a L1 A la myélographie arret total du lipiodol en L1

L enfant est opérée sur les données de la myélographie et du bilan neurologique le neurochirurgien découvre une malformation qui parait purement veineuse et dont le maximum se situe en L1

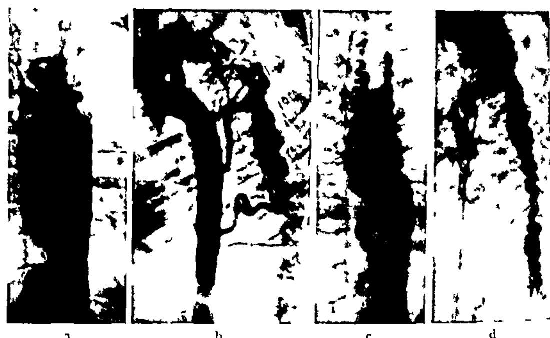


Fig 4 Cas 7 Aortographie par voie fémorale sonde au niveau de D5 Soustraction a) Temps artériel Face Deux pédicules afférents volumineux nés de la face postérieure de l aorte (4e et 6e artères intercostales) Le shunt artério veineux se projette en arrière de D4—D5—D6 il est de structure simple et constitué par un large vaisseau serpentin b) Temps artériel Profil On voit les deux pédicules issus de la face postérieure de l aorte c) Temps veineux Face Les veines de drainage sont remarquables par leur volume et leur extension vers le haut dans la région cervicale et vers le bas jusqu au cone terminal d) Temps veineux Profil Le volumineux vaisseau spiralé s étend de la moelle cervicale au cone terminal

La radiographie simple du rachis montre un important élargissement des distances inter pédiculaires en D2—D3—D4—D5

La myélographie lipiodolée faite en radiocinématographie objective un blocage incomplet en D3 et moule des vaisseaux anormaux que l on voit battre dans l huile opaque

L injection de la malformation est réalisée par aortographie rétrograde fémorale le cathéter est placé dans la crosse de l aorte On objective ainsi la malformation artério veineuse elle commence à s opacifier sur le premier cliché 1/2 seconde après le début de l injection et s étend sur les clichés pris à des temps ultérieurs de D1 à D5 Elle reçoit deux afférences la plus importante par son calibre vient de la 5e artère inter costale aortique droite pénètre le rachis en D5—D6 et atteint le pole inférieur de la malformation l autre de moindre calibre est la branche spinale de la 3 inter costale aortique droite qui atteint le pôle supérieur de l angiome Les efférences veineuses naissent très précocement deux supérieures importantes une inférieure grêle Une laminectomie a révélé le siège postéro latéral droit de l angiome montré une seule afférence artérielle postéro latérale droite et des voies de drainage supérieure

L état neurologique de cet enfant est inchangé à ce jour ou il poursuit sa rééducation dans une maison spécialisée

Cas 6 Garçon de 13 ans Installation à partir de l age de 2 ans par poussées successives avec rémissions d une scoliose d une paraplégie spasmodique avec troubles sphinctériens Le



Fig Cas 8 Aortogr ph e a) Temps arteriel tardif Soustraction Opac ficatio i d enormes d lat tio is ve ieuses en *grappe emplissant* le canal médulla re Deux péd cules afférents l nferieur volumineux naissant d la dorso-spinale d latée de D9 (→) formant une double *courbure* à concavité gauche le supérieur de petit calibre issu de la dorso-spinale de D8 (⟷) asc ndante puis formant une boucle a *con av té* infer eure qui l en mene au pole supérieur de l angiome b) Temps ve neux Soustraction *Le pole inferieur de l* angiome four nit deux ped ules veineux volumineux de grande étendue l un médian sinueux l autre latéral se se jettant dans les plexus *veineux* latero-vertébraux

diagnostic d angiome est porté par la myélographie Un bilan angiographique nous est de mandé avant une intervention chirurgicale sur la scoliose

L aortographie thoracique est faite par voie fémorale Dès le début de l injection s opacifie un volumineux angiome avec shunt artério-veineux précoce nourri par une afference prin cipale venue de la 6 inter costale *droite et* par une afférence accessoire née de la 2 inter costale Une seconde plus tard la masse angiomateuse parait très étendue et s opacifient déjà les premières efférences veineuses

A un temps tardif *(Fig 3c) les efférences* veineuses sont opacifiées étendues et complexes elles aboutissent au plexus extra rachidien *et* a la veine asygos dilatée

Le traitement chirurgical visant à exclure par ligatures successives cet angiome est actuelle ment en cour

Cas 7 Fillette de 3 ans 1/2 Installation en 24 heures d une paraplégie flasque *complète* a ec rétention d urine et an sthésie totale dont la limite supérieure remonte à L1 A la myélo graphie arrêt total du lipiodol en L1

L enfant est opérée sur les *données de* la myelographie et du bilan neurologique le neuro-chirurgien découvre un malformation qui parait purement *veineuse et* dont le maximum se situe en L1



Fig. 6. — Cas 11. Aortographie par voie fémorale. Face. Soustraction. Augmentation de volume de la 3e artère lombaire gauche dont la branche spinale pénètre le rachis entre L3 et L4, remonte jusqu'au bord inférieur de D11—D12 pour redescendre en regard de l'interligne L1—L2 où elle se divise en deux rameaux qui vont l'un au pôle supérieur, l'autre au pôle inférieur d'un fin peloton angiomateux qui se projette en arrière de L1—L2.

Une aortographie est faite quelques semaines plus tard par voie fémorale rétrograde pour préciser les possibilités thérapeutiques. Une première injection au niveau de L1 n'opacifie pas l'angiome. Le cathéter est alors poussé jusqu'en D5. Lors de cette deuxième injection on voit sur les temps précoces (Fig. 4 a et b) deux afférences artérielles volumineuses nées des 4e et 6e inter-costales et un shunt artério-veineux simple constitué par un large vaisseau serpentin. Deux secondes plus tard, les veines de drainage sont remarquables par leur volume et leur extension en haut et en bas (Fig. 4 c et d), ainsi apparaît le large réseau veineux sur lequel s'est arrêté le lipiodol et qu'avait découvert le neurochirurgien. Cet enfant a subi une intervention comportant la ligature et la section des 4e et 6e inter-costales aortiques gauches; cette intervention fut parfaitement supportée sans modification du tableau neurologique. Un mois 1/2 plus tard, survient une aggravation du tableau neurologique avec paralysie des membres supérieurs qui persiste jusqu'à la mort quelques jours plus tard dans un tableau d'hémorragies profuses avec hyperthermie et collapsus terminal. Il n'y a pas eu de vérification nécropsique.

Cas 8. Homme de 25 ans. Début brutal des troubles à l'âge de 9 ans sous la forme d'une paraplégie rapidement régressive. Par la suite, de nouveaux épisodes paralytiques surviennent entrecoupés de rémissions. L'examen neurologique quand nous l'examinons découvre une paraplégie spasmodique, une hypoesthésie à tous les modes dont la limite supérieure est en D12.

L'étude radiologique simple du rachis révèle une scoliose à convexité gauche à sommet en D1 et un élargissement du canal rachidien en D9—D10. La myélographie lipiodolée objective un ralentissement du transit en D11 et des moulages vasculaires évidents.

L'aortographie par voie fémorale permet d'injecter la malformation. La masse angiomateuse injectée à un temps artériel précoce reçoit deux afférences: l'une principale, branche dorso-spinale de la 9e inter-costale gauche aborde le pôle supérieur de l'angiome, l'autre moins importante est la branche dorsospinale de la 8e inter-costale gauche.



Fig 7 a) Vascularisation de la moelle dans son segment dorso-lombaire après injection d une solution de baryum colloidal dans les arteres Pièce anatomique Volumineuse artere d ADAMKIEWICZ qui arrive avec le 10 racine dorsale droite (Cliché emprunté à CORBIN (6)) b) Artere d ADAMKIEWICZ vue au cours d une angiographie rénale chez un sujet de 27 ans

a b

A un temps ultérieur (Fig 5a) les afférences artérielles sont encore visibles la masse angiomateuse s etend de D9 a D11 la sériographie nous a montré en pelotons vasculaires successifs le shunt artério-veineux qui semble siéger au pole supérieur A un temps tardif (Fig 5b) le drainage se fait par deux longs vaisseaux de gros calibre dont l un rejoint la veine lombaire ascendante l autre se perd au delà des limites du cliché

La morphologie de cette malformation alimentée par deux afférences facilement accessibles jointe à l existence d un deficit permanent stable depuis trois ans et déjà important a permis d en visager une intervention visant a affaisser l angiome par ligatures des pédicules nourriciers Cette intervention en deux temps a été bien supportée Son efficacité controlée angiographiquement n a pas été complète car volontairement une des afférences a été respectée l angiographie comme l acte chirurgical ayant montré qu elle fournissait l artère du renflement lombaire Le malade a été un peu amélioré mais nous ne pouvons affirmer que cette amélioration soit à porter au credit de l intervention

Cas 9 Garçon de 11 ans ayant fait deux hémorragies consécutives La *négativité des angiographies cérébrales* un élargissement du canal rachidien en D11 et quelques discrets signes neurologiques ont fait soupçonner le siege dorsal bas de l angiome *Une phlébographie rachidienne* n injecte aucune malformation vasculaire Dans le meme temps opératoire profitant de l anesthésie est faite une *aortographie abdominale* par voie fémorale Au temps artériel de la premiere lombaire droite dilatée nait une *artere ascendante* qui aboutit au pole supérieur d un petit angiome intra rachidien situé en regard de D11—D12 A un temps ultérieur se dessinent l angiome et une volumineuse *efférence* inférieure unique Cette disposition a été vérifiée lors de la laminectomie de décompression

Cas 10 Homme de 60 ans Début à 58 ans par lombalgies sciatique droite déficit du quadriceps droit Deux ans plus tard aggravation à la suite d une chute L examen neurologique en découvrant des signes périphériques et médullaires (signe de Babinski gauche) fait évoquer une atteinte du cone terminal La P L montre un blocage à l épreuve de Stockey et retire *un liquide qui contient 5 éléments par ml et 1 g 70 d albumine par litre*

Les radiographies simples montrent des images arthrosiques banales La myélographie lipiodolée objective un arret incomplet en regard de D12 Une première aortographie est faite qui est négative mais de qualité photographique médiocre L intervention chirurgicale (laminectomie D10—D11—D12) découvre un angiome en D10—D11

Une seconde aortographie est faite quelques semaines plus tard dans de meilleures conditions techniques On opacifie l angiome *en regard de D11 il est nourri par une seule afférence* née de la première artère lombaire gauche Les efférences sont impossibles à préciser

Cas 11 Femme de 31 ans A l age de 27 ans elle souffre de sciatalgie gauche Quatre ans plus tard installation brutale de douleurs radiculaires thoraciques basses et d une paraplegie avec rétention d urine Le diagnostic d angiome est porté par la myélographie lipiodolée Une phlébographie trans épineuse est négative Une laminectomie de décompression est faite sans résultat sur les signes neurologiques

La malade nous est confiée ultérieurement pour préciser les connexions vasculaires de l angiome

Une aortographie thoraco-abdominale par voie fémorale est réalisée Sur un temps artériel tardif (Fig 6) on voit naitre de la 3ᵉ artère lombaire gauche dilatée une artère à trajet intra rachidien ascendant qui après une boucle en regard de D12 se divise en deux rameaux qui vont l un au pôle supérieur l autre au pôle inférieur d un fin peloton angiomateux L image angiographique recoupe l aspect vu à l intervention

Cas 12 Homme de 43 ans Début à 40 ans par des douleurs dans le membre inférieur gauche un an plus tard paraparésie et hypoesthésie globale remontant jusqu à D12

La notion d un angiome cutané lombaire opéré antérieurement jointe à la constatation d un arrêt de lipiodol en arrière de *L2* font pratiquer en juin *1962* une *laminectomie* qui découvre une malformation vasculaire inextirpable au niveau du cone terminal

A la suite de cette intervention une récupération s amorce mais 6 mois plus tard survient une aggravation

Le malade nous est alors adressé pour exploration angiographique L aortographie par voie fémorale objective un anévrisme artério veineux de petit volume nourri par une afférence unique née de la 11ᵉ inter costale aortique gauche représenté par un fin peloton vasculaire en regard de D12 et L1 drainé par une efférence née du pôle inférieur de la malformation

Discussion

Toutes ces observations démontrent que le diagnostic de malformation vasculaire médullaire est possible par l angiographie Notre intention n est pas de nier l'intéret diagnostique de la myélographie lipiodolée, cependant, l angiographie a le mérite d apporter une preuve directe formelle Ce diagnostic a reçu onze fois une confirmation anatomique opératoire ou nécropsique

Précisons que nous n'avons jamais observé de complication en particulier, aucune modification de l état neurologique antérieur du patient, au décours de ces explorations vasculaires

L angiographie permet en outre, un bilan exact de la malformation, elle objective les afférences artérielles le siège du ou des shunts artério veineux et les efférences veineuses Elle montre souvent d ailleurs une lésion dont le shunt et l extension le long de la moelle sont plus complexes que ne le laissait supposer la myélographie et même l exploration chirurgicale Notre observa tion n 7 en est une parfaite illustration

Ainsi l angiographie permet une plus claire vision de la lésion à ce point de vue elle facilite l acte opératoire car elle permet au chirurgien de mieux comprendre la systématisation des vaisseaux anormaux qu il découvre

Cette meilleure étude anatomique due à l angiographie permet quelques considérations nosologiques

Dans tous les cas que nous avons examiné il s agissait de malformations artério veineuses avec shunt Nous n avons jamais retrouvé chez ces malades réunis sans sélection préalable, la classique différenciation entre *angiomes artériels* angiomes artério veineux, angiome racémeux veineux Bien au con traire, nous trouvons une disposition angiographique absolument calquée sur celle de ces malformations au niveau de l encéphale

Considérons tout d abord les afférences artérielles

Les artères aboutissant à la malformation sont des artères *normales* par leur origine leur trajet leur mode de pénétration dans le *rachis* la *concordance* topographique de leur niveau d origine et des segments médullaires intéressés

Ces artères sont anormales par l augmentation de leur calibre témoin de l absence de barrière capillaire et meilleur garant de leur visualisation artério graphique *Elles* sont anormales par leur mode de terminaison au sein d un réseau vasculaire vestigial court circuitant artère et veine

Considérons en second lieu la masse angiomateuse

Elle est toujours difficile à *analyser* La sériographie rapide permet le plus souvent de reconnaître sur les temps précoces, le cœur de la malformation siège *principal des fistules* artério veineuses Rapidement la superposition *noie* dans une même opacité afférences dans leur *segment terminal* vaisseaux angiomateux et efférences Le volume de l *angiome est* très variable selon sa topographie nous y reviendrons *plus loin Son siège* par rapport à la moelle est difficile à *préciser dans un* certain nombre de cas où l on a pu varier les incidences on peut *affirmer le siège* principalement postérieur des vaisseaux anormaux qui *paraît la règle*

Considérons enfin les efférences

Elles sont variables en nombre comme en *volume* et difficilement systéma

tisables. Le fait le plus frappant est qu'elles forment quant à l'espace occupé la partie la plus importante de la malformation dans un grand nombre de cas. Ceci s'explique par la dilatation variqueuse des veines qui se poursuit très loin en aval du shunt artério-veineux, dépassant en haut et en bas l'angiome proprement dit, pour intéresser parfois l'ensemble de la moelle comme dans notre observation n° 7.

Ces constatations permettent de comprendre les erreurs fréquemment commises dans l'appréciation du volume, de la topographie et de la nature même de ces malformations, telle qu'elle est faite lors des interventions chirurgicales ou des vérifications anatomiques. On conçoit ainsi qu'une exploration chirurgicale limitée puisse conclure à un angiome purement veineux si le shunt artério-veineux lui-même et les afférences artérielles sont distantes de la région explorée. Certains travaux récents tel celui d'ANTONI (2), aboutissent aux mêmes conclusions que nous sur la base d'études anatomiques seriées. Le grand mérite de l'angiographie est de clarifier *jusqu'à l'évidence* la structure complexe de ces lésions en visualisant successivement leurs différentes composantes.

Si l'on étudie la malformation dans son ensemble et si l'on veut tenter une systématisation, autant que cela soit permis sur une série restreinte de cas, il semble que l'on puisse distinguer deux types différents :

1) Les fistules artério-veineuses simples, siégeant électivement sur l'extrémité inférieure de la moelle, alimentées par une afférence artérielle unique, représentées par un peloton artério-veineux de petit volume et drainées par une seule efférence veineuse (1 cas dans notre *série*).

2) Les anévrismes cirsoïdes pour lesquels les afférences artérielles sont multiples, la masse angiomateuse volontiers volumineuse, les efférences veineuses importantes et complexes. C'est ainsi que se présentent les angiomes cervicaux (4 cas) et dorsaux (4 cas).

Cette distinction recoupe en la précisant la séparation en *malformations* pauci et pluri segmentaires suggérée par BRION, NETSKI & ZIMMERMAN (4).

Les limites diagnostiques de l'angiographie médullaire sont encore difficiles à préciser compte tenu des 12 cas positifs que nous rapportons, de 3 cas douteux qui n'ont pas été vérifiés et n'ont pas été inclus dans cette statistique et de nos connaissances actuelles des images angiographiques normales des vaisseaux médullaires. Ces références angiographiques normales sont en effet difficiles à obtenir. Nous en avons commencé l'étude, pour le segment terminal, en examinant soigneusement nos dossiers d'angiographies rénales. Lorsque nous la voyons sur *les films (Fig. 7a), l'artère du renflement lombaire ou artère* d'ADAMKIEWICZ (1) a toujours la même morphologie, celle qu'ont révélé les études anatomoradiologiques sur moelle préparée (Fig. 7b) : née d'une inter costale

inférieure ou d une lombaire supérieure cette artère pénètre dans le rachis où elle décrit d abord un trajet ascendant vers la ligne médiane puis une boucle en épingle à cheveux enfin un trajet verticalement descendant du sommet de la boucle se détache une fine artériole ascendante On découvre parfois de fines artères médullaires accessoires Nous n avons pas encore terminé cette étude anatomique pour le renflement lombaire il nous est impossible pour l instant de préciser la fréquence avec laquelle cette artère est accessible à l angiographie chez le sujet normal non plus les facteurs techniques capables de nous fournir d une façon plus fréquente cette image

Il nous faut envisager également les problèmes de diagnostic différentiel qui vont surgir du fait de l utilisation de ces nouvelles méthodes Les anévrismes artériels purs sont exceptionnels au niveau de la moelle, quelques cas en ont été cependant décrits tel celui rapporté par LOMBARDI & MURELLO (26) il est probable que ces anévrismes dans la mesure où ils ne sont pas thrombosés sont accessibles à l angiographie

Les tumeurs intra rachidiennes quand elles sont de nature vasculaire, hémangioblastomes angioréticulomes hémangiopéricytomes sont également susceptibles de s opacifier par voie artérielle DI CHIRO (8) a rapporté en 1957 une observation de maladie de VON HIPPEL LINDAU a double localisation cérébelleuse et cervicale supérieure cette dernière localisation était parfaitement mise en évidence par l angiographie

Enfin il est probable que les autres processus tumoraux intra rachidiens lorsqu ils ont richement vascularisés peuvent avoir eux aussi une traduction angiographique

Pour notre part nous pensons qu un large champ est ouvert a l angiographie médullaire Ce sera là le but de nos recherches dans les années à venir

Pour terminer soulignons que dans notre esprit l intérêt de ces explorations n est pas seulement iconographique et diagnostique Pour la première fois dans le domaine des angiomes de la moelle, a côté de la chirurgie palliative ou aveugle pratiquée jusqu a maintenant elles ouvrent la voie à des solutions chirurgicales nouvelles

Elles permettent d envisager soit des interventions d isolement de ces malformations par ligature de leurs afférences soit sous certaines conditions techniques particulières un abord direct de certaines de ces lésions en bonne connaissance de leurs connexions anatomiques Cinq de nos patients ont été oumis à des tentatives chirurgicales de cet ordre

Il est encore trop tôt pour tirer des conclusions sur la valeur de ces techniques chirurgicales nouvelles Nous savons combien ces problèmes sont complexes, il nous faudra un plus grand nombre de cas un recul plus important dans le temps avant que nos neurochirurgiens puissent faire un bilan valable

RÉSUMÉ

La vascularisation de douze cas de malformation vasculaire de la moelle à localisations cervicales thoraciques ou dorso-lombaires a été étudiée par angiographie Il est possible actuellement, au prix de précautions techniques simples d objectiver, comme pour les mal formations vasculaires cérébrales les afférences les shunts et les efférences Dans tous les cas étudiés ici il s agissait d *angiomes artério veineux avec shunt*

SUMMARY

The vascularisation in twelve cases of vascular malformation of the spinal cord situated in the cervical thoracic or dorsolumbar regions was studied by angiography Observing simple technical precautions it is possible as in the case of cerebral vascular malformation to demon strate afferent and efferent vessels as well as shunts All cases studied had arteriovenous angio-mas with shunt

ZUSAMMENFASSUNG

Es wurde in 12 Fallen die Gefassversorgung von vaskularen Missbildungen des Rucken marks der cervikalen thorakalen oder lumbodorsalen Region mittels Angiographie studiert Unter Einhaltung einfacher technischer Vorsichtsmassnahmen ist es möglich bei den Fallen mit cerebralen vascularen Missbildungen afferente und efferente Gefasse wie auch shunts nachzuweisen In allen untersuchten Fallen handelte es sich um arteriovenose Angiome mit shunt

BIBLIOGRAPHIE

1 ADAMKIEWICZ A Die Blugefässe des Menschlichen Ruckenmarkesoberflache S B Akad Wiss Wien math nat Kl 85 (1882) 101
2 ANTONI N Spinal vascular malformations (angiomas) and myelomalacia Neurology 12 (1962) 795
3 ARSENI C and SAMITCA D Vascular malformations of the spinal cord Acta psychiat scand 34 (1959) 10
4 BRION S NETZKY M and ZIMMERMAN H Vascular malformations of the spinal cord A M A Arch Neurol Psychiat 68 (1952) 339
5 BUCHANAN D and WALKER M Vascular anomalies of the spinal cord in children Amer J Dis Child 61 (1941) 928
6 CORBIN J L Anatomie et pathologie arterielles de la moelle Masson Ed Paris 1961
7 CUSHING H and BAILEY P Tumors arising from the blood vessels of the brain Ch Thomas Baltimore 1928
8 DI CHIRO G Combined retino cerebellar angiomatosis and deep cervical *angiomas* J Neurosurg 14 (1957) 685
9 DJINDJIAN R DUMESNIL M FAURÉ C LEFEBVRE J et LAVEQUE B Etude angiographique d un angiome intra rachidien Rev neurol 106 (1962) 278
10 — — — et TAVERNIER C Angiome medullaire dorsal *Étude clinique et artériographique* Rev neurol 108 (1963) 432

11 — HOLDART R LEFEBVRE J LE BESNERAIS Y et HURTH M L artériographie des angiomes de la moelle (Intérêt nosographique et perspectives thérapeutiques) Rev neurol 109 (1963) 640

12 EPSTEIN J BELLER A and COHEN J Arterial anomalies of the spinal cord J Neurosurg 4 (1949) 45

13 CARCIN R ZULCH K J LAZORTHES G et GRUNER J Pathologie vasculaire de la moelle Rev n urol 106 (1962) 531

14 GINSBOURG M Contribution à l étude des formations vasculaires pathologiques vertebro-medullaires (angiomes vertébraux épiduraux intraduraux) These Les Deux Artisans Ed Paris 1961

15 GRAVELEAU D et PAOLETTI C Malformations et tumeurs vasculaires de la moelle chez l enfant à propos de deux observations Ann Pediat 38 (1963) 310

16 GUILLAIN G et ALAJOUANINE TH Paraplégie par compression due a un volumineux angiocèle de la pie mère spinale Contribution a l étude des compressions médullaires dues a des formations vasculaires pathologiques J Neurol (Brux) 11 (1925) 69

17 GUIOT G HOLDART R et HOLDART F Les malformations vasculaires angiomateuses de la moelle Sem Hop Paris 22 (1946) 809

18 HENSON R A and CROFT P B Spontaneous spinal subarachnoid hemorrhage Quart J Med 25 (1956) 53

19 HOOK O and LIDVALL H Arteriovenous aneurysms of the spinal cord J Neurosurg 15 (1958) 84

20 HOLDART F Contribution a l etude des angiomes de la moelle Angiomes intra-duraux extramédullaires Thèse Paris 1944

21 HURTH M Les anevrysmes artério-veineux de la moelle épinière Considérations anatomo-cliniques et thérapeutiques a propos de onze cas étudiés par artériographie Thèse Foulon Ed Paris 1964

22 LAZORTHES G et coll La vascularisation artérielle de la moelle Recherche anatomiques et applications à la pathologie médullaire et a la pathologie aortique Neuro-chirurgie 4 (1958) 3

23 LEFEBVRE J DJINDJIAN R DUMESNIL M et FAURÉ C Angiomes intrarachidiens et objectivés par angiographie Ann Radiol 6 (1963) 165

24 LOMBARDI G Studio radiologico degli angiomi spinali Radiol m d (Torino) 37 (1951) 716

25 — and PASSERINI A Spinal cord tumors Radiology 76 (1961) 381

26 — et MURELLO C Causes rares d élargissement du canal rachidien Acta radiol 50 (1958) 230

27 — and MIGLIAVACCA F Angiomas of the spinal cord Brit J Radiol 32 (1959) 810

28 MORRIS L Angioma of the cervical spinal cord Radiology 75 (1960) 785

29 NEWMAN M J D Racemose angioma of the spinal cord Quart J Med 28 (1959) 97

30 RAND R W and RAND C W Intraspinal tumors of childhood Charles C Thomas Springfield U S A 1960

31 SADKA M and MERRIT A A Vascular anomaly of the spinal cord illustrated by three case reports Aust Ann Med 5 (1956) 136

32 SELDINGER J I Catheter replacement of the needle in percutaneous arteriography Acta radiol 39 (1953) 368

33 SVIEN H T and BAKER H L Roentgenography and surgical aspects of the vascular anomalies of the spinal cord Surg Gynec Obstet 112 (1961) 729

34 TARLOW I M Spinal extradural hemangioblastoma roentgenographically visualised with diodrast at operation and successfully removed Radiology 49 (1947) 717

35. WALKER A. F. Dilatation of vertebral canal with congenital anomalies of the spinal cord. Amer. J. Roentgenol. 52 (1944) 571.
36. WYBURN MASSON. The vascular abnormalities and tumors of the spinal cord and its membranes. H. Kimpton Ed. London 1943.
37. ZIEDSES DES PLANTES B. Application of the roentgenographic subtraction method in neuroradiology. Acta radiol. 1 (1963) 961.

FROM THE DEPARTMENTS OF SURGICAL NEUROLOGY AND RADIODIAGNOSIS
UNIVERSITY OF EDINBURGH SCOTLAND

TOTAL ANGIOGRAPHY IN SPONTANEOUS INTRACRANIAL HAEMORRHAGE

by

A A DONALDSON

The problem of early location of the site of bleeding in spontaneous intra cranial haemorrhage has been a major concern in our department for many years For seven years it has been our practice to carry out a complete survey of the cerebral circulation in cases of spontaneous intracranial haemorrhage Initially this survey was carried out by individual injection of each carotid artery and each vertebral artery the usual sequence followed being a) bilateral carotid angiography b) 24—48 hours later right vertebral angiography, c) a further 24—48 hours later left vertebral angiography If the clinical features of the case made it necessary the sequence was modified to suit

In 1959 the author reported to the Scottish Radiological Society a first series of 25 consecutive cases of total cerebral angiography (DONALDSON 1959) in which an aneurysmal sac was demonstrated at the origin of the posterior inferior cerebellar artery on the fourth vessel investigated in 4 cases In none of these cases was the clinical syndrome of localising value All the cases were submitted to operative treatment and in each the radiological appearances were confirmed

The delay in making a definitive diagnosis caused us much anxiety because of the risk of further perhaps catastrophic haemorrhage and following on our

35 WALKER A E Dilatation of vertebral canal with congenital anomalies of the spinal cord Amer J Roentgenol 52 (1944), 571
36 WYBURN MASSON The vascular abnormalities and tumors of the spinal cord and its membranes H Kimpton Ed, London 1943
37 ZIEDSES DES PLANTES B Application of the roentgenographic subtraction method in *neuroradiology Acta radiol 1 (1963), 961*

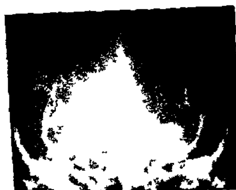


Fig 1 Total cerebral angiography Axillary catheter Aneurysm on right middle cerebral artery

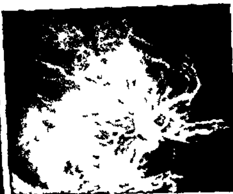


Fig 2 Total cerebral angiography Plethora of vessels in lateral view No aneurysmal sac seen in this and supplementary views

30 to 40 ml of contrast medium are injected by means of a pressure injector The Talley pump is favoured but other similar devices are suitable Posterior lateral and axial views are normally obtained Other views particularly an oblique view may also be helpful In view of the plethora of vessels shown stereo lateral views are probably advisable

Where doubtful appearances are encontered supplementary individual carotid or vertebral injections can be carried out, either at the same session or subsequently Apart from the fatality with the method now discarded for this particular type of case only 1 transient left hemiparesis has occurred in the 76 patients investigated This was in a case where retrograde brachial injection was used recovery took place within a few hours leaving no residual disability There has been no serious circulatory impairment of the limbs following catheterisation In one case of femoral catheterisation however a fairly large haematoma became evident some hours following the procedure

In two cases because of very tortuous or atheromatous vessels the catheterisation was unsuccessful (1 femoral and 1 axillary) and the examinations were completed in the standard manner using carotid and other injections Although the axillary route is preferred for the catheter, in four of our early cases some difficulty was experienced in passing the catheter beyond the branches of the innominate and femoral catheterisation was carried out instead In the case of difficulty with either route it is worth while to proceed immediately to the other We have not encountered this difficulty in our more recent cases using a catheter with a suitably curved tip

Of the 76 examinations 9 were post-operative control These had mostly undergone therapeutic carotid ligation and were important in that vertebral

studies of obstructive cerebral vascular disease by catheterisation of the aortic arch via the femoral artery, it was felt that this provided a means for a rapid preliminary survey of the whole cerebral circulation at the earliest possible time, especially in cases where the clinical syndrome was unhelpful in localisation.

The series here reported totals 76 cases. Femoral catheterisation was used in 39 cases and axillary catheterisation in 28 cases. Of the remaining 9 cases, 7 were subjected to retrograde brachial artery injection by the technique described by KUHN & KUGLER (1963) and the remaining 2 according to the carotid injection technique of ZACLIS (1959).

Although this latter technique produces excellent filling of the intracranial vessels, we consider that the fall in blood pressure that occurs, although present for a very brief time, is too serious for the method to be applied routinely in acute cases of spontaneous intracranial haemorrhage. The only death subsequent to angiography in the present series occurred after employing this method, and autopsy revealed widespread infarction in both cerebral hemispheres. There was an unusually widespread hyaline necrotising arteritis. No aneurysm or other vascular anomaly was found.

Cannulation of the right brachial artery produces excellent filling of the right carotid and vertebral circulations and in 10 % of cases the left carotid circulation is also filled. With left carotid occlusion in 50 % of cases the left carotid circulation is also filled. These figures are according to KUHN & KUGLER and our experience is similar. An important disadvantage is that the upper portion of the left vertebral artery with its posterior inferior cerebellar branch are not usually shown. This, in our view, necessitates further left brachial or left vertebral injection.

Some radiologists consider that the need to expose the brachial artery is a disadvantage, but we find this no problem. The need to carry out supplementary left carotid angiography either by retrograde left temporal injection or direct carotid injection is probably a disadvantage.

Total angiography by axillary or femoral catheterisation appears to be a simple and safe procedure. The majority of the examinations in the present series, i.e. 67 out of 76, have been carried out using this method. The standard Seldinger technique using the large bore needle and a grey Kifa catheter has been employed in adults. The axillary route is preferred as this allows the use of a shorter catheter and permits a more rapid injection of contrast medium. The newer, less viscous, contrast media, such as sodium metrizoate (Triosil) in 60 % or 75 % concentration, or sodium iothalamate (Angio Conray 80) are now used routinely. These less viscous media have greatly improved the contrast obtainable in the intracranial vessels.

For each series of films using the Schonander rapid serial film changer,



Fig 1 Total cerebral angiography Axillary catheter Aneurysm on right middle cerebral artery



Fig 2 Total cerebral angiography Plethora of vessels in lateral view No aneurysmal sac seen in this and supplementary views

30 to 40 ml of contrast medium are injected by means of a pressure injector The Talley pump is favoured but other similar devices are suitable Posterior lateral and axial views are normally obtained Other views particularly an oblique view may also be helpful In view of the plethora of vessels shown stereo lateral views are probably advisable

Where doubtful appearances are encontered supplementary individual carotid or vertebral injections can be carried out either at the same session or subsequently Apart from the fatality with the method now discarded for this particular type of case only 1 transient left hemiparesis has occurred in the 76 patients investigated This was in a case where retrograde brachial injection was used recovery took place within a few hours leaving no residual disability There has been no serious circulatory impairment of the limbs following catheterisation In one case of femoral catheterisation however a fairly large haematoma became evident some hours following the procedure

In two cases because of very tortuous or atheromatous vessels the catheterisation was unsuccessful (1 femoral and 1 axillary) and the examinations were completed in the standard manner using carotid and other injections Although the axillary route is preferred for the catheter in four of our early cases some difficulty was experienced in passing the catheter beyond the branches of the innominate and femoral catheterisation was carried out instead In the case of difficulty with either route it is worth while to proceed immediately to the other We have not encountered this difficulty in our more recent cases using a catheter with a suitably curved tip

Of the 76 examinations 9 were post operative controls These had mostly undergone therapeutic carotid ligation and were important in that vertebral

studies of obstructive cerebral vascular disease by catheterisation of the aortic arch via the femoral artery, it was felt that this provided a means for a rapid preliminary survey of the whole cerebral circulation at the earliest possible time, especially in cases where the clinical syndrome was unhelpful in localisation

The series here reported totals 76 cases Femoral catheterisation was used in 39 cases and axillary catheterisation in 28 cases Of the remaining 9 cases, 7 were subjected to retrograde brachial artery injection by the technique described by KUHN & KUGLER (1963) and the remaining 2 according to the carotid injection technique of ZACLIS (1959)

Although this latter technique produces excellent filling of the intracranial vessels, we consider that the fall in blood pressure that occurs, although present for a very brief time, is too serious for the method to be applied routinely in acute cases of spontaneous intracranial haemorrhage The only death subsequent to angiography in the present series occurred after employing this method, and autopsy revealed widespread infarction in both cerebral hemispheres There was an unusually widespread hyaline necrotising arteritis No aneurysm or other vascular anomaly was found

Cannulation of the right brachial artery *produces excellent filling of the* right carotid and vertebral circulations and in 10 % of cases the left carotid circulation is also filled With left carotid occlusion in 50 % of cases the left carotid circulation is also *filled These figures* are *according to* KUHN & KUGLER and our experience is similar An important disadvantage is that the upper portion of the left vertebral artery with its posterior inferior cerebellar branch are not usually shown This, in our view, necessitates further left brachial or left vertebral injection

Some radiologists consider that the need to expose the brachial artery is a disadvantage, but we find this no problem The need to carry out supplementary left carotid angiography either by retrograde left temporal injection or direct carotid injection is probably a disadvantage

Total angiography by axillary or femoral catheterisation appears to be a simple and safe procedure The majority of the examinations in the present series, i e *67 out of 76, have been carried out using this method* The standard Seldinger technique using the large bore needle and a grey Kifa catheter has been employed in adults The axillary route is preferred as this allows the use of a shorter catheter and permits a more rapid injection of *contrast medium* The newer, less viscous, contrast media, such as sodium metrizoate (Triosil) in 60 % or 75 % concentration, or sodium iothalamate (Angio Conray 80) are now used routinely These less viscous media have greatly improved the contrast obtainable in the intracranial vessels

For each series of films, using the Schonander rapid serial film changer,

graphy was mainly reserved for cases without focal features I am a little disturbed by the relatively large proportion of negative findings but this is probably influenced by the above consideration Obviously longer follow up and further control examinations will be necessary for a complete assessment of the value of the method It is felt however that this is a useful way of approaching the acute spontaneous intracranial haemorrhage and if used with the difficulties clearly in mind it should provide an adequate and rapid method of assessing these cases and perhaps of allowing surgery to be instituted at an earlier stage

SUMMARY

Despite a relatively large proportion of negative findings total cerebral angiography using mainly femoral or axillary catheterisation has proved useful for the localisation of acute spontaneous intracranial haemorrhage Technical aspects of the procedure are discussed

ZUSAMMENFASSUNG

Trotz einer ziemlich grossen Anzahl negativer Resultate hat sich totale Zerebralangiographie vorwiegend hauptsächliche femorale oder axiale Katheterisierung verwendet für die Lokalisierung von spontanen akuten intrakraniellen Hämorrhagien von Wert gezeigt Technische Aspekte dieses Verfahrens werden diskutiert

RÉSUMÉ

Malgré une proportion relativement importante d'examens négatifs l'angiographie cérébrale totale par cathétérisme fémoral ou axillaire s'est montrée utile pour la localisation des hémorragies intracraniennes aigues spontanées L'auteur étudie certains aspects techniques de cet examen

REFERENCES

DONALDSON A A Bilateral vertebral angiography Proc of the Scottish Radiological Society 1959

KLEIN R A and KUGLER H Angiographic methods of choice in evaluation of stroke patients Bull Johns Hopk Hosp 112 (1963) 59

ZACLIS J A new method of cerebral angiography Arch Neuro-psiquiat (S Paulo) 17 (1959)

— and CRUZ O R Arterial occlusions of carotido-vertebral system Arch Neuro-psiquiat (S Paulo) 19 (1961) 295

angiography had not previously been carried out No further aneurysms were found Three of these cases had undergone treatment for arteriovenous malformation and one *in particular was very important in that a saccular aneurysm* on the middle cerebral circulation which had been suspected at the original examination was excluded by total angiography In all cases it was felt that the examination was satisfactory and useful

Of the 76 cases, 36 gave positive findings of aneurysm or arteriovenous malformation Most cases had a single aneurysm which was considered responsible for the intracranial haemorrhage, but 4 cases had multiple aneurysms, two with two aneurysms, one with three aneurysms, and one with a total of five aneurysms There was one basilar aneurysm, and the series is completed by the demonstration of five arteriovenous malformations In 16 of the positive cases, further examination was carried out to obtain further information but this figure of 16 includes a few post operative control examinations following surgery

The *negative examinations, i e negative for aneurysm or other vascular* malformation, were 40 in number Degenerative vascular disease as shown by atheroma or tortuosity of the vessels has not been included as a positive finding although in a number of cases this was present About one third of the negative cases, namely 14, were further examined by carotid and/or vertebral angiography and this invariably tended to confirm the original negative findings The remainder of the negative cases (22) were subjected to further angiography Practically all the negative cases were examples of a minor *intracranial haemorrhage without focal signs Some of the patients were hyper* tensive These patients have been followed up clinically only for periods up to about 18 months No recurrent haemorrhage has been reported except in one case which did *in fact* show an anterior communicating aneurysm At the time of the original total angiography, both the surgeon in charge of the case and the author classified this as doubtful and requiring further investigation, but the patient, a 64 year old diabetic woman with severe generalised arterial disease, hypertension and retinitis, died of recurrent bleeding before further angiography was *carried out, i e within 48 hours This we feel may have been* an error of judgement as, in retrospect, there is no doubt about the presence of the aneurysm (confirmed at autopsy) The patient was, of course, a very poor operative risk

The significance of the figures is difficult to assess at this stage The numbers are small for adequate statistical analysis and the series is complicated by the fact that during the earlier period of the study other cases of spontaneous intracranial haemorrhage which had a definite focal syndrome were investigated by *conventional* carotid and vertebral angiography At this time, total angio

graphy was mainly reserved for cases without focal features I am a little disturbed by the relatively large proportion of negative findings but this is probably influenced by the above consideration Obviously longer follow up and further control examinations will be necessary for a complete assessment of the value of the method It is felt however that this is a useful way of approaching the acute spontaneous intracranial haemorrhage and if used with the difficulties clearly in mind it should provide an adequate and rapid method of assessing these cases and perhaps of allowing surgery to be instituted at an earlier stage

SUMMARY

Despite a relatively large proportion of negative findings total cerebral angiography using mainly femoral or axillary catheterisation has proved useful for the localisation of acute spontaneous intracranial haemorrhage Technical aspects of the procedure are discussed

ZUSAMMENFASSUNG

Trotz einer ziemlich grossen Anzahl negativer Resultate hat sich totale Zerebralangiographie wobei hauptsachl che femorale oder axiale Katheterisierung verwendet wird fur die Lokalisierung von spontanen akuten intrakraniellen Hamorrhagien von Wert gezeigt Technische Aspekte dieses Verfahrens werden diskutiert

RÉSUMÉ

Malgré une proportion relativement importante d examens négatifs l angiographie cérébrale totale par cathéterisme fémoral ou axillaire s est montrée utile pour la localisation des hémorragies intracraniennes aigues spontanées L auteur étudie certains aspects techniques de cet examen

REFERENCES

DONALDSON A A Bilateral vertebral angiography Proc of the Scottish Radiological Society 1959

KUHN R A and KUGLER H Angiographic methods of choice in evaluation of stroke patients Bull Johns Hopk Hosp 11? (1963) 59

ZACLIS J A new method of cerebral angiography Arch Neuro-psiquiat (S Paulo) 17 (1959)

— and CRUZ O R Arterial occlus ons of carotido-vertebral system Arch Neuro-psiquiat (S Paulo) 19 (1961) 295

angiography had not previously been carried out No further aneurysms were found Three of these cases had undergone treatment for arteriovenous malformation and one in particular was very important in that a saccular aneurysm on the middle cerebral circulation which had been suspected at the original examination was excluded by total angiography In all cases it was felt that the examination was satisfactory and useful

Of the 76 cases, 36 gave positive findings of aneurysm or arteriovenous malformation Most cases had a single aneurysm which was considered responsible for the intracranial haemorrhage, but 4 cases had multiple aneurysms, two with two aneurysms, one with three aneurysms, and one with a total of five aneurysms There was one basilar aneurysm, and the series is completed by the demonstration of five arteriovenous malformations In 16 of the positive cases, further examination was carried out to obtain further information but this figure of 16 includes a few post operative control examinations following surgery

The negative examinations, i e negative for aneurysm or other vascular malformation, were 40 in number Degenerative vascular disease as shown by atheroma or tortuosity of the vessels has not been included as a positive finding although in a number of cases this was present About one third of the negative cases, namely 14, were further examined by carotid and/or vertebral angiography and this invariably tended to confirm the original negative findings The remainder of the negative cases (22) were subjected to further angiography Practically all the negative cases were examples of a minor intracranial haemorrhage without focal signs Some of the patients were hypertensive These patients have been followed up clinically only for periods up to about 18 months No recurrent haemorrhage has been reported except in one case which did in fact show an anterior communicating aneurysm At the time of the original total angiography, both the surgeon in charge of the case and the author classified this as doubtful and requiring further investigation, but the patient, a 64 year old diabetic woman with severe generalised arterial disease, hypertension and retinitis, died of recurrent bleeding before further angiography was carried out, i e within 18 hours This we feel may have been an error of judgement as, in retrospect, there is no doubt about the presence of the aneurysm (confirmed at autopsy) The patient was, of course, a very poor operative risk

The significance of the figures is difficult to assess at this stage The numbers are small for adequate statistical analysis and the series is complicated by the fact that during the earlier period of the study other cases of spontaneous intracranial haemorrhage which had a definite focal syndrome were investigated by conventional carotid and vertebral angiography At this time, total angio

graphy was mainly reserved for cases without focal features I am a little disturbed by the relatively large proportion of negative findings but this is probably influenced by the above consideration Obviously, longer follow up and further control examinations will be necessary for a complete assessment of the value of the method It is felt however that this is a useful way of approaching the acute spontaneous intracranial haemorrhage and if used with the difficulties clearly in mind it should provide an adequate and rapid method of assessing these cases and perhaps of allowing surgery to be instituted at an earlier stage

SUMMARY

Despite a relatively large proportion of negative findings total cerebral angiography using mainly femoral or axillary catheterisation has proved useful for the localisation of acute spontaneous intracranial haemorrhage Technical aspects of the procedure are discussed

ZUSAMMENFASSUNG

Trotz einer ziemlich grossen Anzahl negativer Resultate hat sich totale Zerebralangiographie wobei hauptsachliche femorale oder axiale Katheterisierung verwendet wird fur die Lokalisierung von spontanen akuten intrakraniellen Hamorrhagien von Wert gezeigt Technische Aspekte dieses Verfahrens werden diskutiert

RÉSUMÉ

Malgré une proportion relativement importante d examens négatifs l angiographie cérébrale totale par cathéterisme fémoral ou axillaire s est montrée utile pour la localisation des hémorragies intracraniennes a gues spontanées L auteur étudie certains aspects techniques de cet examen

REFERENCES

DONALDSON A A Bilateral vertebral angiography Proc of the Scottish Radiological Society 1959

KUHN R A and KUGLER H Angiographic methods of choice in evaluation of stroke patients Bull Johns Hopk Hosp 112 (1963) 59

ZACLIS J A new method of cerebral angiography Arch Neuro-psiquiat (S Paulo) 17 (1959)

— and CRUZ O R Arterial occlusions of carotido-vertebral system Arch Neuro-psiquiat (S Paulo) 19 (1961) 295

angiography had not previously been carried out No further aneurysms were found Three of these cases had undergone treatment for arteriovenous malformation and one in particular was very important in that a saccular aneurysm on the middle cerebral circulation which had been suspected at the original examination was excluded by total angiography In all cases it was felt that the examination was satisfactory and useful

Of the 76 cases, 36 gave positive findings of aneurysm or arteriovenous malformation Most cases had a single aneurysm which was considered responsible for the intracranial haemorrhage, but 4 cases had multiple aneurysms, two with two aneurysms, one with three aneurysms, and one with a total of five aneurysms There was one basilar aneurysm, and the series is completed by the demonstration of five arteriovenous malformations In 16 of the positive cases, further examination was carried out to obtain further information but this figure of 16 includes a few post operative control examinations following surgery

The negative examinations, i e negative for aneurysm or other vascular malformation, were 40 in number Degenerative vascular disease as shown by atheroma or tortuosity of the vessels has not been included as a positive finding although in a number of cases this was present About one third of the negative cases, namely 14, were further examined by carotid and/or vertebral angiography and this invariably tended to confirm the original negative findings The remainder of the negative cases (22) were subjected to further angiography Practically all the negative cases were examples of a minor intracranial haemorrhage without focal signs Some of the patients were hypertensive These patients have been followed up clinically only for periods up to about 18 months No recurrent haemorrhage has been reported except in one case which did in fact show an anterior communicating aneurysm At the time of the original total angiography, both the surgeon in charge of the case and the author classified this as doubtful and requiring further investigation, but the patient, a 64 year old diabetic woman with severe generalised arterial disease, hypertension and retinitis, died of recurrent bleeding before further angiography was carried out, i e within 48 hours This we feel may have been an error of judgement as, in retrospect, there is no doubt about the presence of the aneurysm (confirmed at autopsy) The patient was, of course, a very poor operative risk

The significance of the figures is difficult to assess at this stage The numbers are small for adequate statistical analysis and the series is complicated by the fact that during the earlier period of the study other cases of spontaneous intracranial haemorrhage which had a definite focal syndrome were investigated by conventional carotid and vertebral angiography At this time, total angio



Fig 1 Thrombosis of internal carotid artery with filling of anterior circulation through a large posterior communicating artery The only neurologic deficit was an upper visual field defect in the right eye

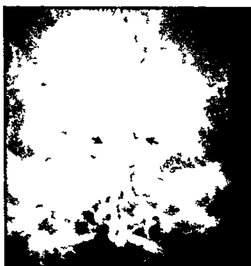


Fig 2 Bilateral vertebral arteriogram by simultaneous injection of the subclavian arteries Filling of all the cerebral arteries in both hemispheres from the posterior circulation through the circle of Willis no residual neurologic deficit but recurrent episodes of aphasia and right hemiparesis

frequently that they cannot always be attributed to extension of clot into peripheral branches or to detachment of emboli This recurrent loss of function apparently on an ischemic basis seems more likely to be related to a temporary failure of the compensatory mechanisms involved in collateral circulation

Such intermittent attacks of transitory paresis or paresthesia may continue without change over many months or years recurring at irregular intervals In a considerable number of individuals they may be forerunners of a permanent neurologic deficit Such a catastrophic event is usually related to the occurrence of complete occlusion of the primary vessel and coincident failure of collateral circulation to compensate for the cessation of flow through the main channel During the period of partial obstruction there is a continuing effort on the part of both the primary vessel and the collaterals to supply the territory of the peripheral branches When complete occlusion of the primary channel occurs the struggle ceases This can result in irreversible deficit if the compensatory mechanisms in collateral circulation are inadequate or in re establishment of a homeostatic situation if they are adequate In the latter circumstance the previously recurring transient ischemic attacks may cease abruptly and the patient remain free of symptoms In some cases

FROM THE DEPARTMENT OF NEUROLOGY (DIRECTOR WILLIAM S FIELDS), BAYLOR UNIVERSITY COLLEGE OF MEDICINE, HOUSTON, TEXAS, U S A

COLLATERAL CIRCULATION IN EXTRACRANIAL VASCULAR OCCLUSION

by

WILLIAM S FIELDS

Angiography has become one of the most important steps in the diagnosis of occlusive vascular disease This technique has contributed much needed information, otherwise unobtainable, regarding the significance of collateral circulation This is especially apparent in respect to understanding two separate but related aspects of cerebral ischemia 1) the protean clinical manifestations of vascular occlusion, and 2) the variability of recovery from functional neurologic deficit

Angiographic studies demonstrate that complete occlusion of one internal carotid artery or one vertebral artery does not always result in permanent functional deficit in neural structures as has been frequently stated in the past Even complete obstruction of both internal carotids, of one carotid and one vertebral, or of both vertebral arteries may not produce marked disability when compensatory mechanisms can immediately become operative

Before occlusion becomes complete, and while stenosis is gradually becoming more severe, the collateral circulation may not adjust rapidly enough to prevent transient episodes of ischemia when alterations occur in the systemic circulation Functional loss during these attacks can be quite severe, but rapid recovery usually follows without residual disability The episodes may recur so



Fig 1 Thrombosis of internal carotid artery with filling of anterior circulation through a large posterior communicating artery The only neurologic deficit was an upper visual field defect in the right eye



Fig 2 Bilateral vertebral arteriogram by simultaneous injection of the subclavian arteries Filling of all the cerebral arteries in both hemispheres from the posterior circulation through the circle of Willis no residual neurologic deficit but recurrent episodes of aphasia and right hemiparesis

frequently that they cannot always be attributed to extension of clot into peripheral branches or to detachment of emboli This recurrent loss of function apparently on an ischemic basis seems more likely to be related to a temporary failure of the compensatory mechanisms involved in collateral circulation

Such intermittent attacks of transitory paresis or paresthesia may continue without change over many months or years recurring at irregular intervals In a considerable number of individuals they may be forerunners of a permanent neurologic deficit Such a catastrophic event is usually related to the occurrence of complete occlusion of the primary vessel and coincident failure of collateral circulation to compensate for the cessation of flow through the main channel During the period of partial obstruction there is a continuing effort on the part of both the primary vessel and the collaterals to supply the territory of the peripheral branches When complete occlusion of the primary channel occurs the struggle ceases This can result in irreversible deficit if the compensatory mechanisms in collateral circulation are inadequate or in re establishment of a homeostatic situation if they are adequate In the latter circumstance the previously recurring transient ischemic attacks may cease abruptly and the patient remain free of symptoms In some cases



Fig 3 Occlusion in proximal portion of the vertebral artery distal portion is filled through numerous collaterals originating from the ipsilateral thyrocervical trunk



Fig 4 Occlusion of the basilar artery in a patient with a history of recurrent episodes of basilar insufficiency Flow from the anterior into the posterior circulation through the circle of Willis Superior cerebellar arteries filled in retrograde direction

where collateral circulation has failed to develop, the initial manifestation of occlusive disease may be catastrophic without antecedent history of recurring transitory episodes

Satisfactory diagnostic evaluation of patients with cerebrovascular insufficiency requires complete demonstration of the arterial tree from the origin of the great vessels in the aortic arch to the intracranial branches of the cerebral arteries It is exceedingly important to have information regarding anomalies, which are very frequent in this part of the circulation It is well known that morphologic variation is common in the circle of Willis and that the integrity of this vascular configuration is of considerable significance in determining whether a patient with cerebrovascular disease will have permanent residual deficit It is for this reason that any study of the craniocervical vessels must include adequate views to outline the circle of Willis

Occlusive lesions are most common at points of bifurcation of the major arteries When thrombosis occurs, the parent vessel becomes occluded, distally at least, to the next point of branching, resulting in classical patterns of colla

teral circulation which differ for each of the major arterial channels Many of these have been described by anatomists in the dissecting room but they can be readily observed angiographically if time and effort are devoted to obtaining adequate films

In view of the increasing interest during the past decade in the surgical treatment of extracranial arterial occlusion it has become much more important to study these patients carefully since decisions regarding operability and prognosis are more readily arrived at if proper angiographic demonstration is obtained

Some examples are presented of angiograms from patients with cerebrovascular disease with either no deficit or minimal residual neurologic deficit (Figs 1 to 4) It will be apparent from the material presented that the presence or absence of disability is dependent upon the adequacy of collateral circulation

SUMMARY

Roentgenographic demonstration of the cranio-cervical collateral circulation has contributed to the understanding of the protean clinical manifestations of arterial occlusion and the variability of recovery from functional deficit Transient attacks of cerebral ischemia cannot always be attributed to emboli but are frequently related to temporary failure of compensatory mechanisms involved in collateral circulation Satisfactory diagnostic evaluation requires complete demonstration of the arterial blood supply to the brain Angiograms are presented from studies of patients with advanced occlusive disease and little or no clinical deficit

ZUSAMMENFASSUNG

Der röntgenologische Nachweis der kraniocervikalen Kollateralzirkulation hat zum Verstehen der verschiedenen klinischen Manifestationen von arteriellem Gefässverschluss und der Verschiedenartigkeit der Vorgänge bei Wiederherstellung von funktionellen Störungen beigetragen Vorübergehende Attacken von cerebraler Ischämie können nicht immer auf Embolie zurückgeführt werden stehen jedoch häufig in Beziehung zu zeitweiligem Versagen von kompensatorischen Vorgängen der Kollateralzirkulation Zufriedenstellende diagnostische Klarlegung erfordert vollständige Darstellung der art Blutversorgung des Gehirns Es werden Angiogramme von Patienten mit avanziertem Gefässverschluss und geringen oder gar keinen klinischen Ausfallserscheinungen gezeigt

RÉSUMÉ

La mise en évidence radiologique de la circulation collatérale cranio-cervicale a contribué à faire comprendre les manifestations cliniques protéiformes de l obstruction artérielle et la variabilité de la récupération des déficits fonctionnels Les crises transitoires d ischémie cérébrale ne peuvent pas toujours être imputées à des embolies mais sont souvent dues à une défaillance temporaire de mécanismes compensateurs qui interviennent dans la circulation collatérale Un bilan diagnostique satisfaisant nécessite la mise en évidence de toutes les artères afférentes au cerveau Les auteurs présentent des angiographies de malades atteints d obstructions artérielle avancées se manifestant par un déficit clinique minime ou nul



Fig 3 Occlusion in proximal portion of the vertebral artery distal portion is filled through numerous collaterals originating from the ipsilateral thyrocervical trunk



Fig 4 Occlusion of the basilar artery in a patient with a history of recurrent episodes of basilar insufficiency Flow from the anterior into the posterior circulation through the circle of Willis Superior cerebellar arteries filled in retrograde direction

where collateral circulation has failed to develop, the initial manifestation of occlusive disease may be catastrophic without antecedent history of recurring transitory episodes

Satisfactory diagnostic evaluation of patients with cerebrovascular insufficiency requires complete demonstration of the arterial tree from the origin of the great vessels in the aortic arch to the intracranial branches of the cerebral arteries It is exceedingly important to have information regarding anomalies, which are very frequent in this part of the circulation It is well known that morphologic variation is common in the circle of Willis and that the *integrity of this vascular configuration is of considerable significance in determining* whether a patient with cerebrovascular disease will have permanent residual deficit It is for this reason that any study of the craniocervical vessels must include adequate views to outline the circle of Willis

Occlusive lesions are most common at points of bifurcation of the major arteries When thrombosis occurs, the parent vessel becomes occluded, distally at least, to the next point of branching, resulting in classical patterns of colla

teral circulation which differ for each of the major arterial channels Many of these have been described by anatomists in the dissecting room but they can be readily observed angiographically if time and effort are devoted to obtaining adequate films

In view of the increasing interest during the past decade in the surgical treatment of extracranial arterial occlusion, it has become much more important to study these patients carefully, since decisions regarding operability and prognosis are more readily arrived at if proper angiographic demonstration is obtained

Some examples are presented of angiograms from patients with cerebrovascular disease with either no deficit or minimal residual neurologic deficit (Figs 1 to 4) It will be apparent from the material presented that the presence or absence of disability is dependent upon the adequacy of collateral circulation

SUMMARY

Roentgenographic demonstration of the cranio-cervical collateral circulation has contributed to the undestanding of the protean clinical manifestations of arterial occlusion and the variability of recovery from functional deficit Transient attacks of cerebral ischemia cannot always be attributed to emboli but are frequently related to temporary failure of compensatory mechanisms involved in collateral circulation Satisfactory diagnostic evaluation requires complete demonstration of the arterial blood supply to the brain Angiograms are presented from studies of patients with advanced occlusive disease and little or no clinical deficit

ZUSAMMENFASSUNG

Der röntgenologische Nachweis der kraniocervikalen Kollateralzirkulation hat zum Verstehen der verschiedenen klinischen Manifestationen von arteriellem Gefässverschluss und der Verschiedenartigkeit der Vorgange bei Wiederherstellung von funktionellen Storungen beigetragen Vorubergehende Attacken von cerebraler Ischamie konnen nicht immer auf Embolie zuruckgeführt werden stehen jedoch haufig in Beziehung zu zeitweiligem Versagen von kompensatorischen Vorgangen der Kollateralzirkulation Zufriedenstellende diagnostische Klarlegung erfordert vollstandige Darstellung der art Blutversorgung des Gehirns Es werden Angiogramme von Patienten mit avanziertem Gefässverschluss und geringen oder gar keinen klinischen Ausfallserscheinungen gezeigt

RÉSUMÉ

La mise en évidence radiologique de la circulation collatérale cranio-cervicale a contribué a fa re comprendre les manifestations cliniques protéiformes de l obstruction artérielle et la variabilité de la récupération des déficits fonctionnels Les crises transitoires d ischémie cérébrale ne peuvent pas toujours être imputées à des embolies mais sont souvent dues a une défaillance temporaire de mécanismes compensateurs qui interviennent dans la circulation collatérale Un bilan diagnostique satisfaisant nécessite la mise en évidence de toutes les a tères afférentes au cerveau Les auteurs présentent des angiographies de malades atteints d obstructions artérielle avancées se manifestant par un déficit clinique minime ou nul



Fig 3 Occlusion in proximal portion of the vertebral artery distal portion is filled through numerous collaterals originating from the ipsilateral thyrocervical trunk



Fig 4 Occlusion of the basilar artery in a patient with a history of recurrent episodes of basilar insufficiency Flow from the anterior into the posterior circulation through the circle of Willis Superior cerebellar arteries filled in retrograde direction

where collateral circulation has failed to develop, the initial manifestation of occlusive disease may be catastrophic without antecedent history of recurring transitory episodes

Satisfactory diagnostic evaluation of patients with cerebrovascular insufficiency requires complete demonstration of the arterial tree from the origin of the great vessels in the aortic arch to the intracranial branches of the cerebral arteries It is exceedingly important to have information regarding anomalies, which are very frequent in this part of the circulation It is well known that morphologic variation is common in the circle of Willis and that the integrity of this vascular configuration is of considerable significance in determining whether a patient with cerebrovascular disease will have permanent residual deficit It is for this reason that any study of the craniocervical vessels must include adequate views to outline the circle of Willis

Occlusive lesions are most common at points of bifurcation of the major arteries When thrombosis occurs, the parent vessel becomes occluded, distally at least, to the next point of branching, resulting in classical patterns of colla

teral circulation which differ for each of the major arterial channels Many of these have been described by anatomists in the dissecting room but they can be readily observed angiographically if time and effort are devoted to obtaining adequate films

In view of the increasing interest during the past decade in the surgical treatment of extracranial arterial occlusion it has become much more important to study these patients carefully since decisions regarding operability and prognosis are more readily arrived at if proper angiographic demonstration is obtained

Some examples are presented of angiograms from patients with cerebrovascular disease with either no deficit or minimal residual neurologic deficit (Figs 1 to 4) It will be apparent from the material presented that the presence or absence of disability is dependent upon the adequacy of collateral circulation

SUMMARY

Roentgenographic demonstration of the cranio-cervical collateral circulation has contributed to the understanding of the protean clinical manifestations of arterial occlusion and the variability of recovery from functional deficit Transient attacks of cerebral ischemia cannot always be attributed to emboli but are frequently related to temporary failure of compensatory mechanisms involved in collateral circulation Satisfactory diagnostic evaluation requires complete demonstration of the arterial blood supply to the brain Angiograms are presented from studies of patients with advanced occlusive disease and little or no clinical deficit

ZUSAMMENFASSUNG

Der rontgenologische Nachweis der kraniocervikalen Kollateralzirkulation hat zum Verstehen der verschiedenen klinischen Manifestationen von arteriellem Gefassverschluss und der Verschiedenartigkeit der Vorgange bei Wiederherstellung von funktionellen Storungen beigetragen Vorubergehende Attacken von cerebraler Ischamie konnen nicht immer auf Embolie zuruckgefuhrt werden stehen jedoch haufig in Beziehung zu zeitweiligem Versagen von kompensatorischen Vorgangen der Kollateralzirkulation Zufriedenstellende diagnostische Klarlegung erfordert vollstandige Darstellung der art Blutversorgung des Gehirns Es werden Angiogramme von Patienten mit avanziertem Gefässverschluss und geringen oder gar keinen klinischen Ausfallserscheinungen gezeigt

RÉSUMÉ

La mise en évidence radiologique de la circulation collatérale cranio-cervicale a contribué a faire comprendre les manifestations cliniques protéiformes de l obstruction artérielle et la variabilité de la récupération des déficits fonctionnels Les crises transitoires d ischemie cérébrale ne peuvent pas toujours être imputées a des embolies mais sont souvent dues a une défaillance temporaire de mécanismes compensateurs qui interviennent dans la circulation collatérale Un bilan diagnostique satisfaisant nécessite la mise en évid nce de toutes les artères afférentes au cerveau Les auteurs présentent des angiographies de malades atteints d obstructions artérielle avancées se manifestant par un deficit clinique minime ou nul

REFERENCES

FIELDS, W. S. and WEIBEL, J. Effects of vascular disorders on the vestibular system. *In* Neurological aspects of auditory and vestibular disorders. Eds., W. S. Fields and B. R. Alford. Charles C. Thomas, Springfield, Ill. 1964.

— BRUETMAN, M. E. and WEIBEL, J. Collateral circulation of the brain. Williams & Wilkins, Baltimore, Maryland, U.S.A. (In press).

WEIBEL, J., FIELDS, W. S., BRUETMAN, M. E., CRAWFORD, E. S. und KIRCHHOFF, P. C. Panarteriographie der intra- und extrakraniellen Zirkulation (Ergebnisse mit perkutaner Subclavia-Katheterisation). Fortsch. Rontgenstr. 99 (1963), 354.

— — Direct percutaneous infraclavicular catheterization of the subclavian artery. J. Neurosurg. 20 (1963), 233.

FROM THE INSTITUTE OF RADIOLOGY (DIRECTOR PROF R BAUER), UNIVERSITY OF TUBINGEN GERMANY

LOCALISATION OF THE VENOUS ANGLE WITH CONSIDERATION PAID TO THE SIZE AND SHAPE OF THE CRANIAL VAULT

by

ERICH FISCHER

Since the first method for localisation of the venous angle of the deep cerebral veins was published in 1951 9 further methods or improvements have become known The multitude of methods proves that there is not yet a sufficiently exact localisation method meeting practical requirements

After examining the existing methods it became clear that an improvement could only be obtained if the individual size and shape of the cranial vault was taken into consideration by a suitable system of coordinates (FISCHER 1963)

The systematic search for a suitable system of coordinates was based on 200 lateral phlebograms

1 Almost all lines and angles between main anatomic points situated in the midline of the cranial vault and of the skull base have been examined with respect to their correlative dependency

2 The angles as demonstrated in Fig 1 of which one side intersects with the venous angle respectively have been checked with respect to their mutual correlation and their correlation to cardinal skull indices such as height length index and angle of the skull base

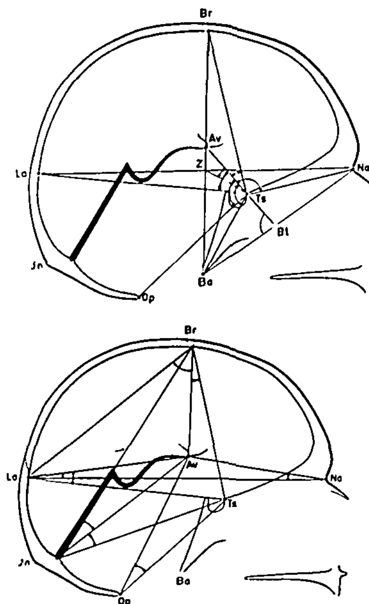


Fig. 1 Angle between angulus venosus and points of the bony skull with angular point at the skull base (top sketch) and at the cranial vault (bottom sketch) Diagrams constructed according to medium values taken from 200 normal cerebral phlebograms of adults Na = nasion Br = endobregma La = endolambda In = endinion Op = opisthion Ba = basion Ts = tuberculum sellae Av = venous angle Z = central point of skull Bl = extension of line Av Ts to base line Na Ba (top sketch) respectively extension of line Br Ts to the base line Na Ba (Fig 2)

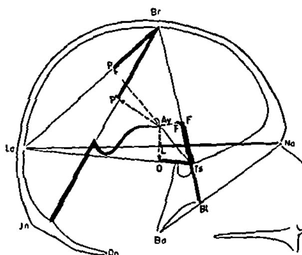


Fig 2 The vertical from venous angle to lines Br Ts Br Bl Br La Br In Na La and Ts La The ratio of the heavily drawn section to the total line has been calculated

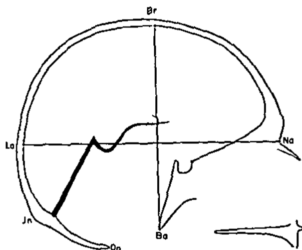


Fig 3 The venous angle always lies above the line Na La and on the average on the line Br Ba

Furthermore vertical lines have been erected in the venous angle on 6 lines as shown in Fig 2 The ratio of the section to the total line has been determined and this again was correlated with a multitude of data

A simple approximative as well as an exact method for localisation of the

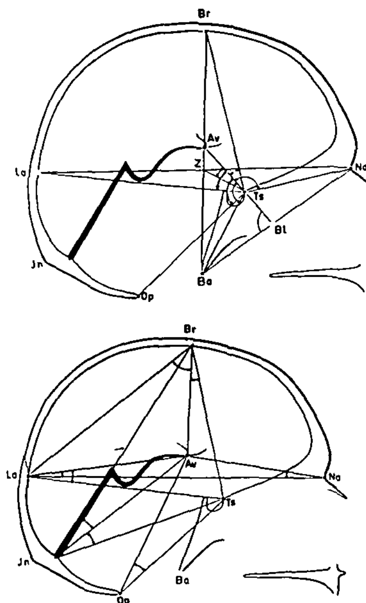


Fig 1 Angle between angulus venosus and points of the bony skull with angular point at the skull base (top sketch) and at the cranial vault (bottom sketch) Diagrams constructed according to medium values taken from 200 normal cerebral phlebograms of adults Na = nasion Br = endobregma La = endolambda In = endinion Op = opisthion Ba = basion Ts = tuberculum sellae Av = venous angle Z = *central point of skull Bl = extension of line Av Tr to base* line Na Ba (top sketch) respectively extension of line Br Ts to the base line Na Ba (Fig 2)

Fig 2 The vertical from venous angle to lines Br Ts Br Bl Br La Br In Na La and Ts La The ratio of the heavily drawn section to the total line has been calculated

Fig 3 The venous angle always lies above the line Na La and on the average on the line Br Ba

Furthermore vertical lines have been erected in the venous angle on 6 lines as shown in Fig 2 The ratio of the section to the total line has bee determined and this again was correlated with a multitude of data

A simple approximative as well as an exact method for localisation of th

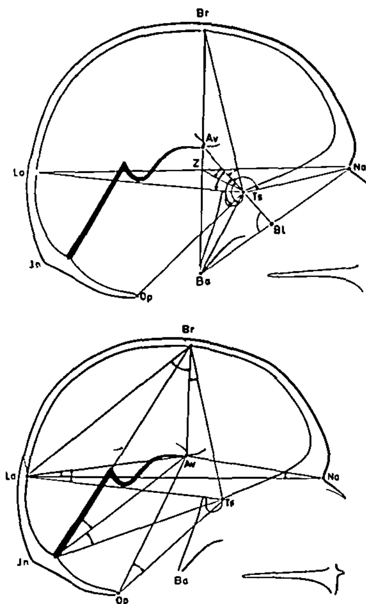


Fig 1 Angle between angulus venosus and points of the bony skull with angular point at the skull base (top sketch) and at the cranial vault (bottom sketch) Diagrams constructed according to medium values taken from 200 normal cerebral phlebograms of adults Na = nasion Br = endobregma La = endolambda In = endinion Op = opisthion Ba = basion Ts = tuberculum sellae Av = venous angle Z = central point of skull Bl = extension of line Av Tr to base line Na Ba (top sketch) respectively extension of line Br Ts to the base line Na Ba (Fig 2)

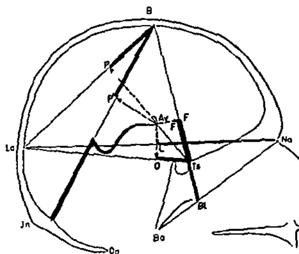


Fig 2 The vertical from venous angle to lines Br Ts Br Bl Br La Br In Na La and Ts La The ratio of the heavily drawn section to the total line has been calculated

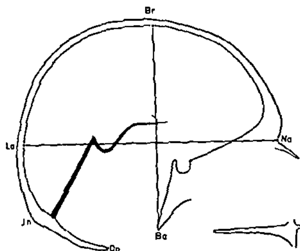


Fig 3 The venous angle always lies above the line Na La and on the average on the line Br Ba

Furthermore vertical lines have been erected in the venous angle on 6 lines as shown in Fig 2 The ratio of the section to the total line has been determined and this again was correlated with a multitude of data

A simple approximative as well as an exact method for localisation of the

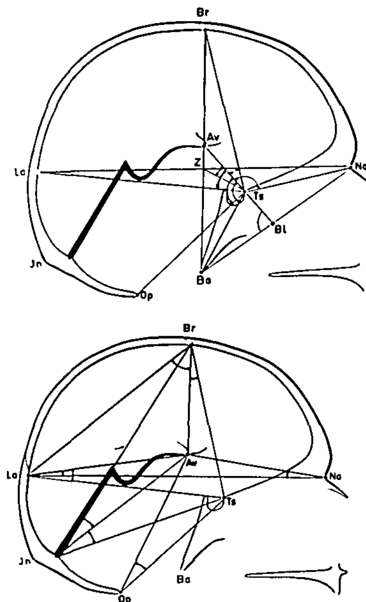


Fig 1 Angle between angulus venosus and points of the bony skull with angular point at the skull base (top sketch) and at the cranial vault (bottom sketch) Diagrams constructed according to medium values taken from 200 normal cerebral phlebograms of adults Na = nasion Br = endobregma La = endolambda In = endinion Op = opisthion Ba = basion Ts = tuberculum sellae Av = venous angle Z = central point of skull Bl = extension of line Av Tr to base line Na Ba (top sketch) respectively extension of line Br Ts to the base line Na Ba (Fig 2)

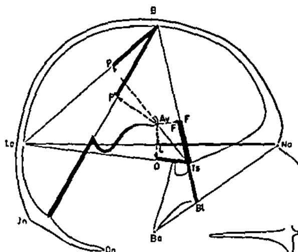


Fig 2 The vertical from venous angle to lines Pr Ts Pr Bl Br La Br In Na La and Ts La The ratio of the heavily drawn section to the total line has been calculated

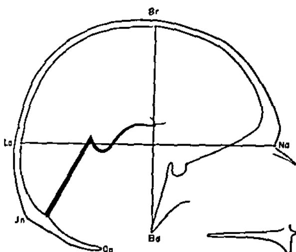


Fig 3 The venous angle always lies above the line Na La and on the average on the line Br Pa

Furthermore vertical lines have been erected in the venous angle on 6 lines as shown in Fig 2 The ratio of the section to the total line has been determined and this again was correlated with a multitude of data

A simple approximative as well as an exact method for localisation of the

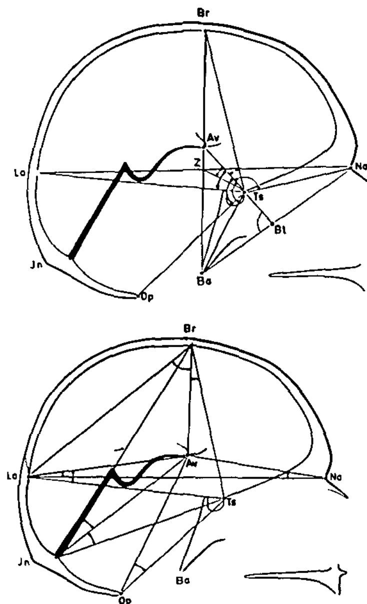


Fig 1 Angle between angulus venosus and points of the bony skull with angular point at the skull base (top sketch) and at the cranial vault (bottom sketch) Diagrams constructed according to medium values taken from 200 normal cerebral phlebograms of adults Na = nasion Br = endobregma La = endolambda In = endinion Op = opisthion Ba = basion Ts = tuberculum sellae Av = venous angle Z = central point of skull Bl = extension of line Av Tr to base line Na Ba (top sketch) respectively extension of line Br Ts to the base line Na Ba (Fig 2)

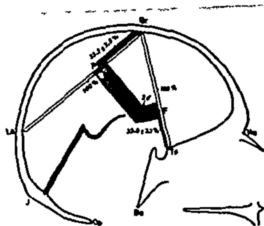


Fig 6 Exact method for determination of the localisation of the venous angle

3 On the bisection line of the angle tuberculum sellae endinion endobregma (Fig 4)

4 On the point of intersection of the vertical lines erected on the anterior third of the line endobregma endolambda and on the inferior third of the line tuberculum sellae endobregma (Fig 5)

The exact method for determining the localisation of the venous angle is as follows (Fig 6)

The line between the tuberculum sellae and endobregma is divided in the ratio of 32 6 ± 3 1 to 67 4 and the line between endobregma endolambda is divided in the ratio of 33 2 ± 2 5 to 66 8 The venous angle is situated on the intersection of the vertical lines erected at these points The exact position of the venous angle can best be achieved from these two lines The other lines as shown in Fig 2 as well as all angles will result in a larger zone of dispersion for the venous angle

In analysing the reference system of the exact method it becomes evident that the line tuberculum sellae endobregma represents a datum for height while the line endobregma endolambda is a measurement for length Both share the endobregma point Height and length of the cranial vault are individually considered Because of the connection of both reference lines in the endobregma point the alteration of size and shape of the cranial vault will be included The essential change of shape of the cranial vault can be expressed by the altered inclination of the two reference lines towards each other In addition the end points of the reference lines are chosen so that they lie in regions of lesser variability (HOWELLS 1957) If one compares this method with conventional processes of localisation as far as they are compatible

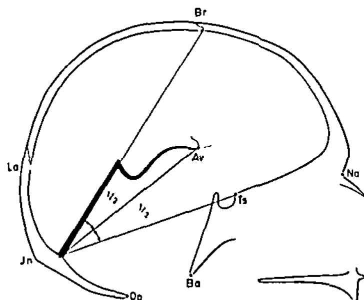


Fig 4 On the average the venous angle lies on the bisection line of the angle Ts Jn Br

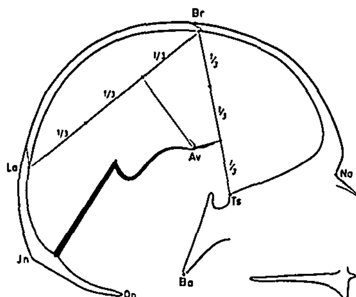


Fig 5 On the average the venous angle lies on the point of intersection of the vertical lines erected on the anterior third of the line Br La and the inferior third of the line Br Ts

venous angle could be achieved by these examinations The position of the venous angle can be determined approximately because it lies

1 Always above the line nasion endolambda (Fig 3)
2 On the average on the line basion endobregma (Fig 3)

MASPES P E e DONEGANI G Flebografia cerebrale normale e pathologica Acta neurochir 3 (1952) 147
RING A Variations in the striate and other cerebral veins affecting measurements of the venous angle Acta neurol 52 (1959) 433
UMBACH W Untersuchungen zur Phlebographie der Hirngefasse Fortschr Rontgenstr 77 (1952) 179
WOLF B S NEWMAN CH M and SCHLESINGER B The diagnostic value of the deep cerebral veins in cerebral angiography Radiology 64 (1955) 161

(MASPES & DONEGANI 1952, JOHANSON 1954, LIN et coll 1955, BRANDT 1959) our method improves the accuracy by 20—40 %

The deep cerebral veins gain more importance for the diagnosis of space occupying lesions by this exact method of localisation for the venous angle

SUMMARY

By taking into consideration the individual size and shape of the cranial vault the normal position of the venous angle of the deep cerebral veins can be localized approximately with the help of a few auxiliary lines and with exactitude by a new simple method

ZUSAMMENFASSUNG

Unter Berucksichtigung der individuellen Grosse und Form des Schadels lasst sich die normale Lage des Angulus venosus der tiefen Hirnvenen 1) durch einige Hilfslinien ungefahr und 2) durch eine neue einfache Methode genau bestimmen

RÉSUMÉ

On peut localiser approximativement l angle veineux des veines cérébrales profondes en tenant compte des dimensions et de la forme de la voute cranienne au moyen de quelques lignes auxiliaires On peut le localiser exactement par une nouvelle méthode simple

REFERENCES

BRANDT P Über die Lage des Foramen Monroi im normalen und pathologischen seitlichen Phlebogramm und uber die Verlagerung der tiefen inneren Venen bei pathologischen Prozessen des Grosshirnes Zbl Neurochir 19 (1959) 130

CURRY R W and CULBRETH G G The normal cerebral angiogram Amer J Roentgenol 65 (1951) 345

FISCHER E Die Lagebeziehung der tiefen Hirnvenen zur Form des Schadels (mit Berucksichtigung der Verlagerung durch raumfordernde intracranielle Prozesse Habilitationsschrift Tubingen 1963

HOWELLS W W The cranial vault factors of size and shape Amer J Phys Anthrop 15 (1957) 19

JOHANSON C The central veins and deep dural sinuses of the brain Acta radiol Suppl 107 1954

LAINE E DELANDTSHEER J M GALIBERT P et DELANTSHEER G Étude phlébographique des tumeurs hémispheriques Neuro chirurgie 1 (1955) 5

LIN P M MOKROHISKY J F STAUFFER H M and SCOTT M The importance of the deep cerebral veins in cerebral angiography with special emphasis on the orientation of the foramen of Monro through the visualisation of the venous angle of the brain J Neurosurg 12 (1955) 256

MASPES P E e DONEGANI G Flebografia cerebrale normale e pathologica Acta neurochir 3 (1952) 147

RING A Variations in the striate and other cerebral veins affecting measurements of the venous angle Acta neurol 52 (1959) 433

UMBACH W Untersuchungen zur Phlebographie der Hirngefasse Fortschr Rontgenstr 77 (1952) 179

WOLF B S NEWMAN CH M and SCHLESINGER B The diagnostic value of the deep cerebral veins in cerebral angiography Radiology 64 (1955) 161

FROM THE DEPARTMENT OF NEUROLOGY, COLLEGE OF PHYSICIANS AND SURGEONS, COLUMBIA UNIVERSITY AND THE NEUROLOGICAL INSTITUTE, PRESBYTERIAN HOSPITAL, NEW YORK, U S A

NEURORADIOLOGIC PROCEDURES IN CHILDREN

Comparison of heavy sedation and general anesthesia

by

R V GROOVER, A M CHUTORIAN and G NELLHAUS

Since encephalography and cerebral angiography were first successfully performed on pediatric patients, many clinical and technical advances have been made In recent years, attention has been given to methods of narcosis employed for these procedures (13) Until the beginning of this decade, general anesthesia was the most widely used However, the widespread successful use of heavy sedation for cardiac catheterization in infants and children has encouraged its use in neurologic procedures This report is a retrospective study of the comparative value of heavy sedation and general anesthesia in the performance of encephalography and cerebral angiography from a large pediatric neurology service

Material The report is based on 812 studies performed on 611 infants and children under 13 years of age admitted to the Babies Hospital and the Neurological Institute of New York between January 1955 and June 1964 The criteria used here are identical to those used in an earlier report (13) A study constitutes each time a patient was either anesthetized or sedated, regardless of the number of procedures performed Patients who underwent surgery

Table 1

Age distribution

Age in years	Encephalography		Angiography		Combined examinations	
	Anesthesia	Sedation	Anesthesia	Sedation	Anesthesia	Sedation
< 1	41	130	8	24	2	5
1—4	61	84	22	39	3	7
5—8	59	68	24	35	2	7
9—12	31	74	20	55	3	8
Total	192	356	74	153	10	27

within 24 hours of their examination are excluded because of the difficulty in distinguishing between complications due to the diagnostic procedures and those due to surgery The patients in both groups were similar with respect to age distribution (Table 1) as well as clinical status and indications for study A total of 276 studies were performed under general anesthesia and 536 under heavy sedation These represent 548 encephalographies 227 cerebral angiographies and 37 combined examinations Of the 644 patients 519 were examined once 99 twice 12 three times, 12 four times and one each five and six times

Techniques All patients were examined upon admission to the hospital and prior to roentgenologic procedures Every attempt was made to have the patient in the best possible condition for the procedures Approximately 75 % of the studies were performed by members of the pediatric neurology service and 25 % by members of the neurosurgery or neuroradiology departments All were performed under the supervision of the Department of Neuroradiology thus affording considerable standardization in technique despite the number of individuals involved

Encephalography was performed with air by the limited fractional replacement method (11 20) The lumbar route was used in the majority of instances, but in small infants this was sometimes combined with direct ventricular puncture via the anterior fontanel

Angiography was performed by the percutaneous approach in all but 2 cases using a No 18 or 20 Cournand needle The contrast material used since 1959 has been methylglucamine diatrizoate (Renografin) Previously Iodopyracet (Diodrast) and sodium diatrizoate (Hypaque) were used in some patients The amount injected varied with the size of the patient the abnormality

Table 2

Sedative dosages for narcosis in children

Age in years	Secobarbital mg/kg	Chlorpromazine mg/kg	Meperidine mg/kg	Atropine
< 1–4	8–10	1.5	1–1.5	0.0[illegible] mg/kg
5–8	5–7	1.0	1–1.5	0.3 mg/pt
9–12	3–4	0.75	1.0	0.4 mg/pt

suspected, and the number of injections required. Prior to arterial injections, patients were given skin and/or intravenous sensitivity tests. Since 1957 a mechanical injector has been used. Previously, manual injections were employed. Simultaneous biplane anteroposterior and lateral serial films were made with each injection. General anesthesia, the most frequently employed method of narcosis from 1955 to 1960, was administered by supervised anesthesiology residents. Premedication drugs varied and were ordered by the anesthesiologist. A nitrous oxide oxygen ether mixture and thiopental (Pentothal) were the anesthetics employed most frequently. Intubation was usually, but not always, employed.

After 1960 heavy sedation was used most frequently for narcosis. The sedative mixture used included secobarbital, chlorpromazine, meperidine and atropine (Table 2). It should be emphasized that the dosage table served as a general guide and was altered according to the procedure and the condition of the patient. Generally, moderate doses of secobarbital plus moderate amounts of meperidine were given for arteriography, while the higher dosages of secobarbital and little or no meperidine were used in encephalography. Chlorpromazine was generally used in both procedures, except in cases of suspected brain stem or hypothalamic lesions, where it was used with great caution. Atropine was generally employed in all procedures. The appropriate mixture was given intramuscularly 45 to 60 minutes prior to the procedure, and was supplemented by local anesthesia of the puncture site at the time of the procedure. Occasionally, additional secobarbital or meperidine was required during the procedure if sedation was inadequate. This was given either intravenously or intramuscularly as the situation indicated.

Results

The degree of technical success was similar in both groups (Table 3). In the anesthetized group, 6.2 % of the examinations were incomplete and inadequate for diagnostic purposes, as compared to 5.6 % of the sedated group. The main

Table 3

Results of the neuroradiologic examinations

Procedure and narcosis	Number of examinations	Unsatisfactory/incomplete	
		Number	Percentage
Anesthesia			
Encephalography	192	11	5 7
Angiography	74	6	8 1
Combined examinations	10	—	—
Total	276	17	6 2
Sedation			
Encephalography	356	23	6 5
Angiography	153	7	4 5
Combined examinations	27	—	—
Total	536	30	5 6

reasons for failures were the introduction of subdural air or difficulty in canulating the artery Untoward reactions to the procedure were a less frequent cause Such reactions occurred during 9 encephalographies 3 under anesthesia and 6 under sedation

Regardless of the type of narcosis used most patients required 3 to 6 hours and occasionally 8 or more hours to become fully alert In the sedated group, the majority of patients were taking and retaining fluids within 2 to 3 hours after their study whereas in the anesthetized group post anesthesia nausea and vomiting delayed oral intake longer Generally patients who received inhalation anesthesia were routinely placed in croupettes for 24 hours after their procedures Such was seldom required in patients in the sedated group Supplementary intravenous fluids were required more often in the anesthetized group Following encephalography approximately 50 % of patients in both groups exhibited fever and/or signs of meningeal irritation lasting 24 to 48 hours It was not unusual for temperatures to reach 39 4° C per rectum during this time However the incidence of temperature elevations above 39 C per rectum dropped sharply after 48 hours

In 106 (13 %) of the 812 studies one or more complications were encountered which were in excess of the expected reactions A total of 64 (7 9 %) occurred in the anesthetized group while 42 (5 1 %) occurred in the sedated group For purposes of classification these complications are divided into 3 types (Table 4) 1 Significant fever and/or meningeal reaction 2 Local and/or miscellaneous, 3 Respiratory and/or cardiovascular

Significant fever and/or meningeal reactions designates those patients who

Table 2

Sedative dosages for narcosis in children

Age in years	Secobarbital mg/kg	Chlorpromazine mg/kg	Meperidine mg/kg	Atropine
< 1—4	8—10	1 5	1—1 5	0 02 mg/kg
5—8	5—7	1 0	1—1 5	0 3 mg/pt
9—12	3—4	0 75	1 0	0 4 mg/pt

suspected, and the number of injections required Prior to arterial injections, patients were given skin and/or intravenous sensitivity tests Since 1957 a mechanical injector has been used Previously, manual injections were employed Simultaneous biplane anteroposterior and lateral serial films were made with each injection General anesthesia, the most frequently employed method of narcosis from 1955 to 1960, was administered by supervised anesthesiology residents Premedication drugs varied and were ordered by the anesthesiologist A nitrous oxide oxygen ether mixture and thiopental (Pentothal) were the anesthetics employed most frequently Intubation was usually, but not always, employed

After 1960 heavy sedation was used most frequently for narcosis The sedative mixture used included secobarbital, chlorpromazine, meperidine and atropine (Table 2) It should be emphasized that the dosage table served as a general guide and was altered according to the procedure and the condition of the patient Generally, moderate doses of secobarbital plus moderate amounts of meperidine were given for arteriography, while the higher dosages of secobarbital and little or no meperidine were used in encephalography Chlorpromazine was generally used in both procedures, except in cases of suspected brain stem or hypothalamic lesions, where it was used with great caution Atropine was generally employed in all procedures The appropriate mixture was given intramuscularly 45 to 60 minutes prior to the procedure, and was supplemented by local anesthesia of the puncture site at the time of the procedure Occasionally, additional secobarbital or meperidine was required during the procedure if sedation was inadequate This was given either intravenously or intramuscularly as the situation indicated

Results

The degree of technical success was similar in both groups (Table 3) In the anesthetized group, 6 2 % of the examinations were incomplete and inadequate for diagnostic purposes, as compared to 5 6 % of the sedated group The main

Table 3

Results of the neuroradiologic examinations

Procedure and narcosis	Number of examinations	Unsatisfactory/incomplete	
		Number	Percentage
Anesthesia			
Encephalography	192	11	5.7
Angiography	74	6	8.1
Combined examinations	10	—	—
Total	276	17	6.2
Sedation			
Encephalography	356	23	6.5
Angiography	153	7	4.5
Combined examinations	27	—	—
Total	536	30	5.6

reasons for failures were the introduction of subdural air or difficulty in canulating the artery. Untoward reactions to the procedure were a less frequent cause. Such reactions occurred during 9 encephalographies, 3 under anesthesia and 6 under sedation.

Regardless of the type of narcosis used most patients required 3 to 6 hours and occasionally 8 or more hours to become fully alert. In the sedated group, the majority of patients were taking and retaining fluids within 2 to 3 hours after their study whereas in the anesthetized group post anesthesia nausea and vomiting delayed oral intake longer. Generally, patients who received inhalation anesthesia were routinely placed in croupettes for 24 hours after their procedures. Such was seldom required in patients in the sedated group. Supplementary intravenous fluids were required more often in the anesthetized group. Following encephalography approximately 50 % of patients in both groups exhibited fever and/or signs of meningeal irritation lasting 24 to 48 hours. It was not unusual for temperatures to reach 39.4° C per rectum during this time. However, the incidence of temperature elevations above 39° C per rectum dropped sharply after 48 hours.

In 106 (13 %) of the 812 studies one or more complications were encountered which were in excess of the expected reactions. A total of 64 (7.9 %) occurred in the anesthetized group while 42 (5.1 %) occurred in the sedated group. For purposes of classification, these complications are divided into 3 types (Table 4):
1. Significant fever and/or meningeal reaction. 2. Local and/or miscellaneous.
3. Respiratory and/or cardiovascular.

Significant fever and/or meningeal reactions designates those patients who

Table 2

Sedative dosages for narcosis in children

Age in years	Secobarbital mg/kg	Chlorpromazine mg/kg	Meperidine mg/kg	Atropine
< 1—4	8—10	1.5	1—1.5	0.02 mg/kg
5—8	5—7	1.0	1—1.5	0.3 mg/pt
9—12	3—4	0.75	1.0	0.4 mg/pt

suspected, and the number of injections required. Prior to arterial injections, patients were given skin and/or intravenous sensitivity tests. Since 1957 a mechanical injector has been used. Previously, manual injections were employed. Simultaneous biplane anteroposterior and lateral serial films were made with each injection. General anesthesia, the most frequently employed method of narcosis from 1955 to 1960, was administered by supervised anesthesiology residents. Premedication drugs varied and were ordered by the anesthesiologist. A nitrous oxide oxygen ether mixture and thiopental (Pentothal) were the anesthetics employed most frequently. Intubation was usually, but not always, employed.

After 1960 heavy sedation was used most frequently for narcosis. The sedative mixture used included secobarbital, chlorpromazine, meperidine and atropine (Table 2). It should be emphasized that the dosage table served as a general guide and was altered according to the procedure and the condition of the patient. Generally, moderate doses of secobarbital plus moderate amounts of meperidine were given for arteriography, while the higher dosages of secobarbital and little or no meperidine were used in encephalography. Chlorpromazine was generally used in both procedures, except in cases of suspected brain stem or hypothalamic lesions, where it was used with great caution. Atropine was generally employed in all procedures. The appropriate mixture was given intramuscularly 15 to 60 minutes prior to the procedure, and was supplemented by local anesthesia of the puncture site at the time of the procedure. Occasionally, additional secobarbital or meperidine was required during the procedure if sedation was inadequate. This was given either intravenously or intramuscularly as the situation indicated.

Results

The degree of technical success was similar in both groups (Table 3). In the anesthetized group, 6.2 % of the examinations were incomplete and inadequate for diagnostic purposes, as compared to 5.6 % of the sedated group. The main

means while the other required suturing of a rent in the carotid artery Allergic reactions to contrast material occurred in 3 instances Neurologic sequelae were rare and generally transient One child with a clinical diagnosis of degenerative central nervous system disease was studied under general anesthesia He experienced significant hypoxia during the procedure and had his first seizure 3 days after the encephalography Three sedated patients exhibited transient hemiparesis following the procedure — two encephalographies and one combined examination A child with a brain stem glioma exhibited signs of block and increased intracranial pressure following encephalography requiring ventricular drainage for relief

The respiratory and/or cardiovascular complications are subtyped into fatal serious, and less serious Serious designates notable hypoxia such as laryngospasm, apnea, cardiac arrest prolonged arrhythmia and the like Less serious designates brief bronchospasm, hypotension tachycardia and croupiness Such complications were encountered in 20 % of the patients studied under general anesthesia and in 4 7 % of the patients studied under heavy sedation All 3 fatalities occurred in patients examined under general anesthesia (Table 4)

Less serious complications were encountered in 51 instances — 36 in the anesthetized group and 15 in the sedated group A total of 27 patients of the former group had to be kept in oxygen and mist for 36 hours or more because of laryngo-tracheitis bronchitis and/or pneumonia Two exhibited notable transient respiratory distress during induction In 7 infants of less than 3 year transient hypothermia and hypotension was observed following encephalography Of the patients belonging to the sedated group 2 exhibited bronchitis or bronchopneumonia 11 exhibited transient respiratory distress either during or after the procedure, and 2 exhibited transient mild cardiac arrhythmias

In all 26 serious complications were encountered — 16 in the anesthetized group and 10 in the sedated group In the former group apnea or respiratory obstruction ensued necessitating active respiratory assistance In 7 patients severe laryngeal edema pneumonia or other serious respiratory difficulties were encountered In 7 sedated patients severe apnea and/or cardiac arrest occurred requiring intubation assisted respirations, and in 2 instances external cardiac massage Irregular respirations labile blood pressures and cardiac arrhythmias were encountered in 2 patients with brain stem glioma following encephalography and severe circulatory collapse occurred during an arteriography under heavy sedation in a child with a craniopharyngioma

Three deaths were encountered in the total of 813 studies All three occurred in patients given general anesthesia i e an overall mortality rate of 0 37 % or a rate of 1 1 % of procedures performed under general anesthesia

Table 4

Complications in children

Procedure and narcosis	No of examinations	With complications		Fever and/or meningeal		Local and miscellaneous		Respiratory and/or cardiovascular					
								Fatal		Serious		Less serious	
		No	%	No	%	No	%	No	%	No	%	No	%
Anesthesia													
Encephalography	192	38	19.8	6	3.1	2	1.0	1	0.5	11	5.7	21	10.9
Angiography	74	22	29.7	1	1.4	7	9.5	2	2.7	3	4.1	14	19.0
Combined	10	4	40.0	0	0	1	10.0	0	0	2	20.0	1	10.0
Total	276	64	23.2	7	2.5	10	3.6	3	1.1	16	5.8	36	13.0
Sedation													
Encephalography	356	24	6.7	8	2.2	3	0.8	0	0	8	2.2	10	2.7
Angiography	153	15	9.9	1	0.7	7	4.5	0	0	2	1.3	5	3.3
Combined	27	3	11.1	3	11.1	0	0	0	0	0	0	0	0
Total	536	42	7.8	12	2.2	10	1.9	0	0	10	1.9	15	2.8

exhibited temperatures greater than 39° C per rectum and/or significant meningeal reactions lasting more than 48 hours Such complications were similarly encountered in both groups (Table 4) There was one case of bacterial meningitis following encephalography This occurred in a hydrocephalic infant with a previous Spitz-Holter shunt and two prior, ostensibly eradicated, episodes of staphylococcus albus bacteremia Three cases of severe aseptic meningitis occurred following encephalographies performed on successive days by different physicians All cultures were negative and it was presumed that probably some chemical irritant had been present on the equipment used In the remaining 13 instances, the fever and meningeal signs subsided with supportive therapy and no cause other than the procedure could be implicated In the two incidences of fever following angiography, one occurred in a child with pseudotumor cerebri and the second in an infant with infantile hemiplegia

Local and miscellaneous complications include excessive hematoma formation, allergic reactions to contrast material and neurologic sequelae Hematomas of such size as to produce tracheal shift prolonged hoarseness and/or difficulties in swallowing occurred in 8 instances following angiography — 5 in the anesthetized group and 3 in the sedated group In 3 instances persistent bleeding from the puncture site was encountered Two were controlled by local

means, while the other required suturing of a rent in the carotid artery Allergic reactions to contrast material occurred in 3 instances Neurologic sequelae were rare and generally transient One child with a clinical diagnosis of degenerative central nervous system disease was studied under general anesthesia He experienced significant hypoxia during the procedure and had his first seizure 3 days after the encephalography Three sedated patients exhibited transient hemiparesis following the procedure — two encephalographies and one combined examination A child with a brain stem glioma exhibited signs of block and increased intracranial pressure following encephalography requiring ventricular drainage for relief

The respiratory and/or cardiovascular complications are subtyped into *fatal serious* and *less serious* Serious designates notable hypoxia such as laryngospasm apnea cardiac arrest prolonged arrhythmia and the like Less serious designates brief bronchospasm hypotension tachycardia, and croupiness Such complications were encountered in 20 % of the patients studied under general anesthesia and in 4 7 % of the patients studied under heavy sedation All 3 fatalities occurred in patients examined under general anesthesia (Table 4)

Less serious complications were encountered in 51 instances — 36 in the anesthetized group and 15 in the sedated group A total of 27 patients of the former group had to be kept in oxygen and mist for 36 hours or more because of laryngo tracheitis bronchitis and/or pneumonia Two exhibited notable transient respiratory distress during induction In 7 infants of less than 3 years transient hypothermia and hypotension was observed following encephalography Of the patients belonging to the sedated group 2 exhibited bronchitis or bronchopneumonia 11 exhibited transient respiratory distress either during or after the procedure, and 2 exhibited transient mild cardiac arrhythmias

In all 26 serious complications were encountered — 16 in the anesthetized group and 10 in the sedated group In the former group apnea or respiratory obstruction ensued necessitating active respiratory assistance In 7 patients severe laryngeal edema pneumonia or other serious respiratory difficulties were encountered In 7 sedated patients severe apnea and/or cardiac arrest occurred requiring intubation assisted respirations and in 2 instances external cardiac massage Irregular respirations labile blood pressures and cardiac arrhythmias were encountered in 2 patients with brain stem gliomas following encephalography and severe circulatory collapse occurred during an arteriography under heavy sedation in a child with a craniopharyngioma

Three deaths were encountered in the total of 813 studies All three occurred in patients given general anesthesia, i e an overall mortality rate of 0 37 % or a rate of 1 1 % of procedures performed under general anesthesia

Table 4

Complications in children

Procedure and narcosis	No of examinations	With complications		Fever and/or meningeal		Local and miscellaneous		Respiratory and/or cardiovascular					
								Fatal		Serious		Less serious	
		No	%	No	%	No	%	No	%	No	%	No	%
Anesthesia													
Encephalography	192	38	19.8	6	3.1	2	1.0	1	0.5	11	5.7	21	10.9
Angiography	74	22	29.7	1	1.4	7	9.5	2	2.7	3	4.1	14	19.0
Combined	10	4	40.0	0	0	1	10.0	0	0	2	20.0	1	10.0
Total	276	64	23.2	7	2.5	10	3.6	3	1.1	16	5.8	36	13.0
Sedation													
Encephalography	356	24	6.7	8	2.2	3	0.8	0	0	8	2.2	10	2.7
Angiography	153	15	9.9	1	0.7	7	4.5	0	0	2	1.3	5	3.3
Combined	27	3	11.1	3	11.1	0	0	0	0	0	0	0	0
Total	536	42	7.8	12	2.2	10	1.9	0	0	10	1.9	15	2.8

exhibited temperatures greater than 39° C per rectum and/or significant meningeal reactions lasting more than 48 hours. Such complications were similarly encountered in both groups (Table 4). There was one case of bacterial meningitis following encephalography. This occurred in a hydrocephalic infant with a previous Spitz Holter shunt and two prior, ostensibly eradicated, episodes of staphylococcus albus bacteremia. Three cases of severe aseptic meningitis occurred following encephalographies performed on successive days by different physicians. All cultures were negative and it was presumed that probably some chemical irritant had been present on the equipment used. In the remaining 13 instances, the fever and meningeal signs subsided with supportive therapy and no cause other than the procedure could be implicated. In the two incidences of fever following angiography, one occurred in a child with pseudotumor cerebri and the second in an infant with infantile hemiplegia.

Local and miscellaneous complications include excessive hematoma formation, allergic reactions to contrast material, and neurologic sequelae. Hematomas of such size as to produce tracheal shift, prolonged hoarseness and/or difficulties in swallowing occurred in 8 instances following angiography — 5 in the anesthetized group and 3 in the sedated group. In 3 instances persistent bleeding from the puncture site was encountered. Two were controlled by local

means while the other required suturing of a rent in the carotid artery Allergic reactions to contrast material occurred in 3 instances Neurologic sequelae were rare and generally transient One child with a clinical diagnosis of degenerative central nervous system disease was studied under general anesthesia He experienced significant hypoxia during the procedure and had his first seizure 3 days after the encephalography Three sedated patients exhibited transient hemiparesis following the procedure — two encephalographies and one combined examination A child with a brain stem glioma exhibited signs of block and increased intracranial pressure following encephalography requiring ventricular drainage for relief

The respiratory and/or cardiovascular complications are subtyped into fatal serious and less serious Serious designates notable hypoxia such as laryngospasm apnea cardiac arrest prolonged arrhythmia and the like Less serious designates brief bronchospasm hypotension tachycardia and croupiness Such complications were encountered in 20 % of the patients studied under general anesthesia and in 4 7 % of the patients studied under heavy sedation All 3 fatalities occurred in patients examined under general anesthesia (Table 4)

Less serious complications were encountered in 51 instances — 36 in the anesthetized group and 15 in the sedated group A total of 27 patients of the former group had to be kept in oxygen and mist for 36 hours or more because of laryngo-tracheitis bronchitis and/or pneumonia Two exhibited notable transient respiratory distress during induction In 7 infants of less than 3 years transient hypothermia and hypotension was observed following encephalography Of the patients belonging to the sedated group 2 exhibited bronchitis or bronchopneumonia 11 exhibited transient respiratory distress either during or after the procedure and 2 exhibited transient mild cardiac arrhythmias

In all 26 serious complications were encountered — 16 in the anesthetized group and 10 in the sedated group In the former group apnea or respiratory obstruction ensued necessitating active respiratory assistance In 7 patients severe laryngeal edema pneumonia or other serious respiratory difficulties were encountered In 7 sedated patients severe apnea and/or cardiac arrest occurred requiring intubation assisted respirations and in 2 instances external cardiac massage Irregular respirations labile blood pressures and cardiac arrhythmias were encountered in 2 patients with brain stem gliomas following encephalography and severe circulatory collapse occurred during an arteriography under heavy sedation in a child with a craniopharyngioma

Three deaths were encountered in the total of 813 studies All three occurred in patients given general anesthesia i e an overall mortality rate of 0 37 % or a rate of 1 1 % of procedures performed under general anesthesia

Table 5

Age of patients and incidence of complications

Narcosis	No of examinations	Complications	Percentages
Anesthesia			
< 1 year	51	20	39
1— 4 years	86	23	27
5— 8 years	85	16	19
9—12 years	54	5	9
Total	276	64	23 2
Sedation			
< 1 year	159	15	9 4
1— 4 years	130	15	11 6
5— 8 years	110	6	5 6
9—12 years	137	6	4 4
Total	536	42	7 8

Case reports

Case 1 The first fatality was a 3 month old female weighing 4 5 kg with bilateral subcapsular cataracts microcephaly and diarrhea of unknown etiology She was initially premedicated with 550 mg tribromethanol rectally which was partially expelled An additional 250 mg tribromethanol was given rectally and 20 mg pentobarbital was given intramuscularly General inhalation anesthesia was then administered without intubation Following the removal of 3 0 ml of spinal fluid and the instillation of 10 ml air via the lumbar subarachnoid space respiratory and cardiac arrest ensued The patient was promptly intubated and open cardiac massage instituted but to no avail

Case 2 The second death occurred in an 8 week old female weighing 5 kg with a massive hemangioma of the left face and scalp Intracranial extension was ruled out by a left common carotid arteriogram performed under general anesthesia Ligation of the left external carotid was planned but the patient experienced cardiac arrest while being transferred from angiography to the operating room Open chest cardiac massage was performed with return of cardiac action after 3 minutes The infant never regained consciousness and expired 5 days later

Case 3 The third death occurred in an 8 year old female weighing 30 kg who had an acute severe intracerebral and subarachnoid hemorrhage secondary to a ruptured arterio venous malformation of the right frontal lobe She was stuporous but arousable before the examination and was given general anesthesia and intubated A left common carotid angiography with a cross compression test was performed followed by left vertebral angiography During the procedure the patient exhibited signs of tonsillar and tentorial herniation which were treated with intravenous urea Subsequently she developed respiratory arrest and frank pulmonary edema requiring assisted respirations for the 12 following hours She never regained consciousness and expired 3 days later

In both groups proportionately greater incidence of complications was encountered in patients under 5 years of age This incidence was significantly greater in patients studied under general anesthesia This was most marked in the infants under 1 year where the complication rate was four times greater in patients studied under general anesthesia (Table 5)

Discussion

The occurrence of three fatalities in the anesthetized group might be considered merely fortuitous however one cannot escape the fact that no deaths occurred in almost twice as many procedures performed on comparable patients under heavy sedation The two deaths occurring in infants under 1 year of age were felt by the physicians in charge to be due primarily to the effects of anesthesia and their general conditions rather than to the procedures performed Careful review of the charts substantiated this The third death was most likely due to the severity of the child s illness and to the complications occurring during the study rather than to the effects of general anesthesia per se

Significant and/or meningeal reactions and local and/or miscellaneous complications are attributable to the procedures themselves The incidence of such complications was similar in both the anesthetized and sedated groups However notable difference in the incidence of respiratory and/or cardiovascular complications was apparent between the two groups for such complications occurred approximately 4 5 times more frequently in examinations performed under general anesthesia (Table 4) Since other factors were comparable it may be assumed that the primary reason for the significant difference was in the method of narcosis used Support for such a conclusion may be found by reviewing the inherent risks of general anesthesia in pediatric patients (1 15 19)

General anesthesia has generally been advocated for narcosis in neuroradiologic procedures in pediatric patients for two reasons — to decrease the incidence of technical failures and to decrease the incidence of local complications (3 4 8 10) However in our experience 6 2 % of the studies performed under general anesthesia were incomplete and unsatisfactory while 5 6 % of the studies performed under heavy sedation were unsatisfactory Local complications such as excessive hematoma formation injury to the arterial wall and the like occurred in 3 6 % of the procedures performed under general anestheisa and in 1 9 % of studies under heavy sedation

In addition to the obvious advantage of reducing the incidence of cardiorespiratory complications the use of heavy sedation obviates the need for the direct attendance of an anesthesiologist Technically the procedures are more

easily performed in the absence of elaborate anesthetic equipment. The time required for the performance is reduced, since the patient arrives in the radiology department in the sedated state. Following the roentgenologic examination the patient is less prone to nausea and vomiting, takes oral fluids earlier, and requires less nursing care in the post study period than the comparable patient who has had general anesthesia. Thus, heavy sedation has been the narcosis of choice for the performance of encephalography and cerebral angiography in pediatric patients in our department since 1960. General anesthesia has been reserved for those patients who are to be operated upon immediately after the examination.

The use of sedation for narcosis in neuroradiologic procedures in infants and children is not new. A detailed review of the subject by two of the authors is set forth in an earlier report (13). In 1930, CROTHERS and his coworkers suggested the use of repeated small doses of morphine in encephalography. Four years later, RUPILIUS advocated sedation for encephalography, pointing out the dangers of general anesthesia. More recently BAMBERGER & MATTHES suggested a combination of chlorpromazine, promethazine and meperidine for patients undergoing encephalography.

The precise amount and type of sedation an infant or child may require in order that a given procedure may be successfully performed remains largely a matter of experience. This involves many variables, such as the clinical status of the patient, the skill and speed of the operator and roentgen technician, and the extent and duration of the examination. The sedative mixture used in this report included secobarbital, chlorpromazine, meperidine and atropine (Table 2). It should be emphasized that this dosage schedule was not absolute, but rather served as a guide and was varied according to the procedure and the condition of the patient. Also, this combination of drugs is not to be considered the best or the only satisfactory sedative mixture, for there appears to be no universal agreement as to which drug or combination of drugs is best (7, 14). Rather it may be said that this combination of drugs has been successful in our hands. It is interesting to note that combinations of drugs similar both quantitatively and qualitatively to the drugs outlined here have been recommended as preanesthetic medication for infants and children (4, 9, 17, 18, 19).

Little or no meperidine in combination with the outlined dosages of secobarbital, chlorpromazine and atropine was given for encephalography because of the tendency for meperidine to produce hypotension and emesis. These appear to be exaggerated by the postural gyrations in encephalography. The patients sedated for arteriography usually received the lower dosage of secobarbital, in addition to meperidine, chlorpromazine, and atropine, because of the pain associated with cannulation of the artery. Chlorpromazine was

used in very low dosages if at all in patients with suspected hypothalamic or brain stem lesions because of the distinct impression that such patients were especially sensitive to the drug Atropine was used in both types of procedures primarily because of its inhibition of reflex vagal activity and depression of pressoreceptors

The main reasons for inadequate sedation of patients in the present series was either miscalculation on the part of the operator as to the amount of sedation needed or unavoidable delays in starting the procedure so that the optimal period of sedation had passed Adequate sedation in such cases was usually achieved by giving a supplemental injection of either secobarbital or meperidine intravenously or intramuscularly as the situation indicated Oversedation was an extremely rare problem In one instance a small infant received twice the ordered amount of sedation His procedure was cancelled and performed successfully under more reasonable sedation at a later date He tolerated the seemingly alarming overdosage very well The importance of administering the sedative mixture at least 45 to 60 minutes before the procedure cannot be overemphasized If the patient is unduly disturbed before maximal sedative effect has taken place we have found the patient reacts suboptimally to what would otherwise have been adequate sedation However if the medication is given 45 to 60 minutes before the procedure, we have found the patient arrives in the radiologic department sedated and sleeping Generally he arouses somewhat when positioned but promptly returns to sleep when left alone He usually arouses again when the area of the puncture site is infiltrated with local anesthesia However if then left undisturbed for a few minutes he returns to his ataractic state and the operator may proceed with the examination

Conclusions

A total of 812 neuroradiologic examinations, not followed in 24 hours by surgery in infants and children under 13 years of age have been reviewed retrospectively Of these, 276 were performed under general anesthesia while 536 were performed under heavy sedation The two groups were similar with respect to age distribution and clinical status of the patients indications for roentgen examination and methods used The methods of narcosis employed in the patients were outlined and discussed

Complications were encountered in 106 (13 %) of the 812 procedures Sixty four (23 2 %) of the examinations performed under general anesthesia and 42 (7 8 %) of those performed under heavy sedation were complicated Complications attributable to the procedures themselves were essentially comparable in both groups whereas respiratory and cardiovascular complica

tions were encountered 4 5 times more frequently in the anesthetized patients This preponderance was evident in all age groups, but it was most marked in infants under one year The degree of technical success under both types of narcosis was comparable Thus, it has been shown that neuroradiologic procedures in pediatric patients can be performed under heavy sedation with promise of comparable technical success and with less risk to the patient than under general anesthesia

Acknowledgements

This work was supported in part by special traineeships BT 1101 (Dr Groover) BT 619 (Dr Chutorian) and BT 468 (Dr Nellhaus) from The National Institute of Neurological Diseases and Blindness United States Public Health Service

SUMMARY

A total of 812 neuroradiologic studies not followed in 24 hours by surgery in infants and children under 13 years of age have been reviewed retrospectively 276 were performed under general anesthesia and 536 under heavy sedation The two groups were similar with respect to age distribution clinical status of the patients indications and methods used The methods of narcosis employed are outlined and discussed

ZUSAMMENFASSUNG

Es wurden insgesamt 812 neuroradiologische Studien von Kleinkindern und Kindern unter 13 Jahren retrospektiv durchgesehen Ein chirurgischer Eingriff innerhalb 24 Stunden nach der neuroradiologischen Untersuchung war nicht vorgenommen worden In 276 Fallen war die Untersuchung in allgemeiner Anasthesie in 536 Fallen nach Verabreichung von starken Sedativa durchgefuhrt worden Beide Gruppen sind sich ahnlich in der Altersverteilung im klinischen Status den Indikationen und Untersuchungsmethoden Die angewandten Methoden der Narkose werden aufgezeigt und besprochen

RÉSUMÉ

Les auteurs ont passé en revue 812 examens neuroradiologiques chez des nourrissons et des enfants de moins de 13 ans qui n ont pas été suivis d intervention chirurgicale dans les 24 heures 276 de ces examens avaient été faits sous anesthésie générale et 536 sous sédation profonde Les deux groupes étaient semblables en ce qui concerne la distribution selon l âge l état clinique des malades les indications et les méthodes utilisées Les auteurs décrivent et étudient les méthodes de narcose employées

REFERENCES

1 ADRIANI J Anesthesia in infancy and childhood G P 27 (1963) 82
2 BAMBERGER P and MATTHES A Anfälle im Kindesalter p 277 S Karger Basel 1959
3 BRANDT S GARDE M DE LA and ROSENDAL T The technique of pneumoencephalography in children Acta paediat Suppl 103 (1955) 61
4 BRUNNER S and BUCHMANN G Anesthesiologic problems in pediatric radiology Amer J Roentgenol 89 (1963) 1075
5 CROTHERS B VOGT E C and ELEY R C Encephalography in cases with fixed lesions of the brain Amer J Dis Child 40 (1930) 227
6 DANDY W E Ventriculography following the injection of air into the cerebral ventricles Ann Surg 68 (1918) 5
7 DOUGHTY A G The evaluation of premedication in children Proc roy Soc Med 52 (1959) 823
8 FARMER T W Ed Pediatric Neurology Hoeber Medical Division Harper & Row New York Evanston and London 1964
9 FREEMAN A and BACHMANN L Pediatric anesthesia An evaluation of preoperative medication Anesth Analg 38 (1959) 429
10 HAGBERG B et coll Pneumoencephalography in early infancy Risks clinical indications and technical considerations Acta paediat Suppl 117 (1959) 61
11 LINDGREN E Some aspects on the technique of encephalography *Acta radiol 31 (1949)* 161
12 MONIZ E Diagnostic des tumeurs cérébrales et épr uve de l encéphalographie arterielle p 372 Masson & Cie Paris 1931
13 NEUHAUS G and CHUTORIAN A Narcosis for neuroradiologic procedures in children Arch Neurol 10 (1964) 485
14 RACKOW H and SALANITRE E A dose effect study of preoperative medication in children Anesthesiology 23 (1962) 747
15 — — and GREEN L T Frequency of cardiac arrest associated with anesthesia in infants and children Pediatrics 28 (1961) 697
16 RUPILIUS K Über Zerebrale Storungen im Kindesalter und ihre Enzephalographische Diagnostik Arch Kinderheilk 102 (1934) 194 103 (1934) 39
17 SANDOVE M S and FRYE T J Preoperative sedation and production of a quiescent state in children promethazine meperidine scopolamine sedation J Amer med Ass 164 (1957) 1729
18 SMITH R M and JEFFRIES M The evaluation of sedative agents for preoperative use in children Anesth Analg 38 (1958) 166
19 SMITH R M Anesthesia for infants and children 2nd edition C V Mosby Company St Louis 1963
20 TAVERAS J M The Small Pneumoencephalogram Clinical Neurosurgery Vol 7 p 214 The Williams & Wilkins Co Baltimore 1961

tions were encountered 4 5 times more frequently in the anesthetized patients This preponderance was evident in all age groups, but it was most marked in infants under one year The degree of technical success under both types of narcosis was comparable Thus, it has been shown *that neuroradiologic procedures in pediatric patients can be performed under heavy sedation with promise of comparable technical success and with less risk to the patient than under general anesthesia*

Acknowledgements

This work was supported in part by special traineeships BT 1101 (Dr Groover) BT 619 (Dr Chutorian) and BT 468 (Dr Nellhaus) from The National Institute of Neurological Diseases and Blindness United States Public Health Service

SUMMARY

A total of 812 neuroradiologic studies not followed in 24 hours by surgery in infants and children under 13 years of age have been reviewed retrospectively 276 were performed under general anesthesia and 536 under heavy sedation The two groups were similar with respect to age distribution clinical status of the patients indications and methods used The methods of narcosis employed are outlined and discussed

ZUSAMMENFASSUNG

Es wurden insgesamt 812 neuroradiologische Studien von Kleinkindern und Kindern unter 13 Jahren retrospektiv durchgesehen Ein chirurgischer Eingriff innerhalb 24 Stunden nach *der neuroradiologischen Untersuchung war nicht vorgenommen worden* In 276 Fällen war die Untersuchung in allgemeiner Anästhesie in 536 Fällen nach Verabreichung von starken Sedativa durchgeführt worden Beide Gruppen sind sich ähnlich in der Altersverteilung im klinischen Status den Indikationen und Untersuchungsmethoden Die angewandten Methoden der Narkose werden aufgezeigt und besprochen

RESUMÉ

Les auteurs ont passé en revue 812 examens neuroradiologiques chez des nourrissons et des enfants de moins de 13 ans qui n ont pas été suivis d intervention chirurgicale dans les 24 heures 276 de ces examens avaient été faits sous anesthésie générale et 536 sous sédation profonde Les deux groupes étaient semblables en ce qui concerne la distribution selon l age l état clinique des malades les indications et les méthodes utilisées Les auteurs décrivent et étudient les méthodes de narcose employées

REFERENCES

1 ADRIANI J Anesthesia in infancy and childhood G P 27 (1963) 82
2 BAMBERGER P and MATTHES A Anfälle im Kindesalter p 277 S Karger Basel 1959
3 BRANDT S GARDE M DE LA and ROSENDAL T The technique of pneumoencephalography in children Acta paediat Suppl 103 (1955) 61
4 BRUNNER S and BUCHMANN G Anesthesiologic problems in pediatric radiology Amer J Roentgenol 89 (1963) 1075
5 CROTHERS B VOGT E C and ELEY R C Encephalography in cases with fixed lesions of the brain Amer J Dis Child 40 (1930) 227
6 DANDY W E Ventriculography following the injection of air into the cerebral ventricles Ann Surg 68 (1918) 5
7 DOUGHTY A G The evaluation of premedication in children Proc roy Soc Med 52 (1959) 823
8 FARMER T W Ed Pediatric Neurology Hoeber Medical Division Harper & Row New York Evanston and London 1964
9 FREEMAN A and BACHMANN L Pediatric anesthesia An evaluation of preoperative medication Anesth Analg 38 (1959) 429
10 HAGBERG B et coll Pneumoencephalography in early infancy Risks clinical indications and technical considerations Acta paediat Suppl 117 (1959) 61
11 LINDGREN E Some aspects on the technique of encephalography Acta radiol 31 (1949) 161
12 MONIZ E Diagnostic des tumeurs cérébrales et épreuve de l encéphalographie arterielle p 372 Masson & Cie Paris 1931
13 NELLHAUS G and CHUTORIAN A Narcosis for neuroradiologic procedures in children Arch Neurol 10 (1964) 485
14 RACKOW H and SALANITRE E A dose effect study of preoperative medication in children Anesthesiology 23 (1962) 747
15 — — and GREEN L T Frequency of cardiac arrest associated with anesthesia in infants and children Pediatrics 28 (1961) 697
16 RUPILIUS K Über Zerebrale Storungen im Kindesalter und ihre Enzephalographische Diagnostik Arch Kinderheilk 102 (1934) 194 103 (1934) 32
17 SANDOVE M S and FRYE T J Preoperative sedation and production of a quiescent state in children promethazine meperidine scopolamine sedation J Amer med Ass 164 (1957) 1729
18 SMITH R M and JEFFRIES M The evaluation of sedative agents for preoperative use in children Anesth Analg 38 (1958) 166
19 SMITH R M Anesthesia for infants and children 2nd edition C V Mosby Company St Louis 1963
20 TAVERAS J M The Small Pneumoencephalogram Clinical Neurosurgery Vol 7 p 214 The Williams & Wilkins Co Baltimore 1961

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR PROF HIROMU TACHIIRI),
OSAKA UNIVERSITY HOSPITAL, OSAKA, JAPAN

THE THALAMOPERFORATE ARTERY

by

KAZUO HARA and YASUSADA FUJINO

The small arteries arising from the posterior part of the circle of Willis have received little attention in the literature The increased use of vertebral angiography has however led to demonstration and the technique evolved at our centre has proved valuable in the diagnosis of deep seated cerebral tumours

Autopsy studies

Twenty two fresh brain specimens were used in an effort to form estimates of the normal anatomic patterns of the small arteries emerging from the posterior part of the circle of Willis The basilar arteries having been injected with gelatin barium solution (LINDBLOM, JOHANSON), the brains were fixed in 10 % formalin solution The macroscopic and roentgenographic findings were then reviewed

The many small arteries that arise from the posterior part of the circle of Willis may be divided into the superficial branches, which reach the surface of the brain, and the perforating branches, which pass through the cerebral parenchyma The latter are mostly more than 0 2 mm in diameter and are outlined in the vertebral angiogram, while the superficial branches, less than 0 2 mm in diameter, are difficult or impossible to show (Fig 1)



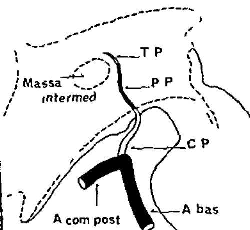
Fig 1 Autopsy specimen Thalan operforate a tery (→) and posterior communicating ar tery (⟷)



F g 2 Sag ttal section through normal autopsy specimen showing cisternal part of thalamoper fo ate artery (arrow)



Fig 3 Lateral roentgenogram of normal uiopsy pe men Thalamoperforate artery (arrow) and trans t on l reg o between cis t rnal pa t nd p renchymal part (needle point)



F g 4 D gram of d vision of the thalamoperforate artery C.P Cisternal part P P Parenchymal part T P Termi al part

Branches emerging from the terminal part of the basilar artery Some perforating branches arise from the terminal part of the basilar artery These may range in number from two to six and in size from 0 2 to 0 8 mm and arise proximal to the bifurcation of the basilar artery and the posterior communicating artery

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR: PROF. HIROMU TACHIIRI),
OSAKA UNIVERSITY HOSPITAL, OSAKA, JAPAN

THE THALAMOPERFORATE ARTERY

by

KAZUO HARA and YASUSADA FUJINO

The small arteries arising from the posterior part of the circle of Willis have received little attention in the literature. The increased use of vertebral angiography has however led to demonstration and the technique evolved at our centre has proved valuable in the diagnosis of deep seated cerebral tumours.

Autopsy studies

Twenty two fresh brain specimens were used in an effort to form estimates of the normal anatomic patterns of the small arteries emerging from the posterior part of the circle of Willis. The basilar arteries having been injected with gelatin barium solution (LINDBLOM, JOHANSON), the brains were fixed in 10 % formalin solution. The macroscopic and roentgenographic findings were then reviewed.

The many small arteries that arise from the posterior part of the circle of Willis may be divided into the superficial branches, which reach the surface of the brain, and the perforating branches, which pass through the cerebral parenchyma. The latter are mostly more than 0.2 mm in diameter and are outlined in the vertebral angiogram while the superficial branches, less than 0.2 mm in diameter, are difficult or impossible to show (Fig. 1).



Fig 1 Autopsy specimen Thalamoperforate artery (→) and posterior communicating artery (⟶)



Fig 2 Sagittal section through normal autopsy specimen showing cisternal part of thalamoperforate artery (arrow)



Fig 3 Lateral roentgenogram of normal autopsy specimen Thalamoperforate artery (arrow) and transitional region between cisternal part and parenchymal part (needle point)

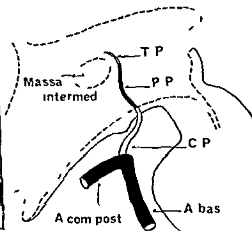


Fig 4 Diagram of division of the thalamoperforate artery C P Cisternal part P P Parenchymal part T P Terminal part

Branches emerging from the terminal part of the basilar artery Some perforating branches arise from the terminal part of the basilar artery These may range in number from two to six and in size from 0 2 to 0 8 mm and arise proximal to the bifurcation of the basilar artery and the posterior communicating artery

FROM THE DEPARTMENT OF RADIOLOGY (DIRECTOR PROF HIROMU TACHIRI), OSAKA UNIVERSITY HOSPITAL, OSAKA, JAPAN

THE THALAMOPERFORATE ARTERY

by

KAZUO HARA and YASUSADA FUJINO

The small arteries arising from the posterior part of the circle of Willis have received little attention in the literature The increased use of vertebral angiography has however led to demonstration and the technique evolved at our centre has proved valuable in the diagnosis of deep seated cerebral tumours

Autopsy studies

Twenty two fresh brain specimens were used in an effort to form estimates of the normal anatomic patterns of the small arteries emerging from the posterior part of the circle of Willis The basilar arteries having been injected with gelatin barium solution (LINDBLOM, JOHANSON), the brains were fixed in 10 % formalin solution The macroscopic and roentgenographic findings were then reviewed

The many small arteries that arise from the posterior part of the circle of Willis may be divided into the superficial branches which reach the surface of the brain, and the perforating branches, which pass through the cerebral parenchyma The latter are mostly more than 0 2 mm in diameter and are outlined in the vertebral angiogram while the superficial branches less than 0 2 mm in diameter, are difficult or impossible to show (Fig 1)

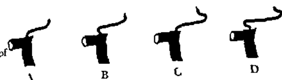


Fig 6 Variations of cisternal part of thalamoperforate artery (solid line)

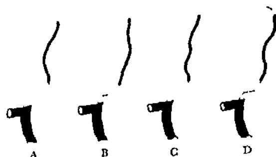


Fig 7 Variations of parenchymal part of thalamoperforate artery (solid line)



Fig 8 Lateral roentgenogram of autopsy specimen The perforating branch arises from the posterior communicating artery (arrow)

main types, A B C and D the characteristic variations being well displayed in the lateral view (Fig 6) Most of the 22 cases of the present series were of Type A but some examples of a combination of two or more types were also recognized

The thalamoperforate artery may also be divided into Types A B C and D in its parenchymal part (Fig 7) This part of the artery runs upwards in one or two curves with a tendency for the right and left sides to be symmetrical



Fig 5 A p roentgenogram of normal autopsy brain Parenchymal part (→) and terminal part (⟶)

One of these arteries was termed the thalamoperforate artery by reason of its relation to the thalamus by HAYMAKER or artère du pédicule thalamoperforé by TESTUT The thalamoperforate artery usually runs backwards through the interpeduncular fossa where it gives off one or two rami As it leaves the basilar artery, it follows the sigmoid curve to reach the parenchyma where it runs vertically into the perforated substance (Fig 2) The remainder of the branches arising from the more distal part of the terminal part of the basilar artery and some branches of the thalamoperforate artery are distributed over the cerebral peduncles

Branches emerging from the posterior communicating artery These may also be divided into perforating and superficial branches The latter are very small and usually penetrate the lateral perforate area so named by KODAMA

Roentgenography

A study of a sagittal section of the cerebral hemispheres at the level of the circle of Willis (Fig 3) indicates that the thalamoperforate artery may be divided into three parts cisternal, parenchymal and terminal (Fig 4) The cisternal part of the thalamoperforate artery lies in the extracerebral space from which it runs upwards and slightly forwards along the wall of the third ventricle through the parenchyma The parenchymal part courses outwards and forwards or outwards and backwards to become the terminal part after passing the third ventricle Filling of the thalamoperforate artery and its relation to surrounding structures are well shown in an a p roentgenogram of an autopsy specimen (Fig 5) The terminal part of the thalamoperforate artery is seen in the lateral view to pass round the intermediate mass, however, the terminal part is not always clearly demonstrated

The thalamoperforate artery in its cisternal part may be divided into four



Fig 13 Stenosis of Sylvian duct producing dilatation of third ventricle and stretching of parenchymal part of thalamoperforate artery (arrow)



Fig 14 Stretching and forward and downward displacement of parenchymal part of thalamoperforate artery in pinealoma (arrow)



Fig 15 Tumour arising from the quadrigeminal plate Stretching and forward displacement of thalamoperforate artery (arrow)



Fig 16 Infiltrating tumour in thalamus Irregularity of thalamoperforate artery (arrow) and pathologic vessels

suitable for study and proved to be particularly informative (Fig 9) Minor movements of the head or poor contrast filling may however produce blurring of the artery The transitional portion between its cisternal and parenchymal parts lies in a straight line as seen at autopsy an appearance characteristic enough to allow easy differentiation of the two parts

The branches arising from the posterior communicating artery visible in a vertebral angiogram in a quarter of 60 cases are commonly observed in young



Fig 9 Vertebral angiogram Normal thalamoperforate artery (arrow)

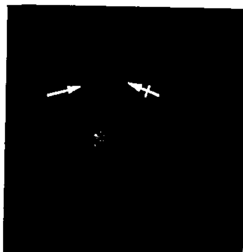


Fig 10 Filling of entire perforating branch from posterior communicating artery (→) and thalamoperforate artery (+→)

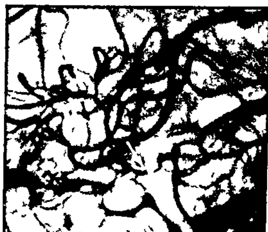


Fig 11 Normal vertebral angiogram with bilateral carotid compression showing perforating branch from posterior communicating artery (arrow) and thalamoperforate artery



Fig 12 Stretching and backward displacement of thalamoperforate artery in craniopharyngioma

Type A was frequently observed and Types C and D with two gentle curves were noted in a few cases Some branches occasionally reached the hypothalamic region The perforating branches arising from the posterior communicating artery may be divided into cisternal and parenchymal, although classification is impossible because of unusual variations in the course of these branches (Fig 8)

As the thalamoperforate artery is usually superimposed on the cerebellar or other arteries in the a p vertebral angiogram, only the lateral view was



Fig 13 Stenos s of Syl ian duct producing dila tation of th rd ventr le and tretching of paren chymal part of thalamoperforate artery (arrow)



Fig 14 Stretch ng and forward and downwa d d placem nt of parenchymal part of thalamoperforate artery in p nealoma (arrow)



F g 15 Tumour a s ng from the quad igem nal pl te Stretch ng and forward d splacement of thalam perforate artery (arrow)



Fig 16 Infiltrating tumou in th alamus Irreg ularity of thalamoperforate artery (arrow) and patholog c ve sels

suitable for study and proved to be particularly informative (Fig 9) Minor movements of the head or poor contrast filling may however produce blurring of the artery The transitional portion between its cisternal and parenchymal parts lies in a straight line as seen at autopsy, an appearance characteristic enough to allow easy differentiation of the two parts

The branches arising from the posterior communicating artery, visible in a vertebral angiogram in a quarter of 60 cases, are commonly observed in young



Fig 9 Vertebral angiogram Normal thalamoperforate artery (arrow)

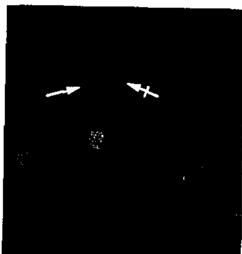


Fig 10 Filling of entire perforating branch from posterior communicating artery (→) and thalamoperforate artery (↔)



Fig 11 Normal vertebral angiogram with bilateral carotid compression showing perforating branch from posterior communicating artery (arrow) and thalamoperforate artery



Fig 12 Stretching and backward displacement of thalamoperforate artery in craniopharyngioma

Type A was frequently observed and Types C and D with two gentle curves were noted in a few cases Some branches occasionally reached the hypothalamic region The perforating branches arising from the posterior communicating artery may be divided into cisternal and parenchymal, although classification is impossible because of unusual variations in the course of these branches (Fig 8)

As the thalamoperforate artery is usually superimposed on the cerebellar or other arteries in the a p vertebral angiogram, only the lateral view was



Fig 13 Stenosis of Syl ian duct producing dila t tion of th rd ventr cle and stretching of paren chymal part of thalamoperforate artery (arrow)



Fi 14 Stretching and forward and downward displacement of parenchymal part of thalamo pe forate artery in p nealoma (arrow)



Fig 15 Tumour ari ng from the quadrigeminal plate Stretch g and forward d splacement of thalamoperfor te artery (arrow)



Fig 16 Infiltrating tumour in thalamus Irreg ular ty of thalamoperforate artery (arrow) and path log c vessels

suitable for study and proved to be particularly informative (Fig 9) Minor movements of the head or poor contrast filling may however produce blurring of the artery The transitional portion between its cisternal and parenchymal parts lies in a straight line as seen at autopsy an appearance characteristic enough to allow easy differentiation of the two parts

The branches arising from the *posterior* communicating artery visible in a vertebral angiogram in a quarter of 60 cases are commonly observed *in* young



Fig 9 Vertebral angiogram Normal thalamoperforate artery (arrow)



Fig 10 Filling of entire perforating branch from posterior communicating artery (→) and thalamoperforate artery (↔)



Fig 11 Normal vertebral angiogram with bilateral carotid compression showing perforating branch from posterior communicating artery (arrow) and thalamoperforate artery



Fig 12 Stretching and backward displacement of thalamoperforate artery in craniopharyngioma

Type A was frequently observed and Types C and D with two gentle curves were noted in a few cases Some branches occasionally reached the hypothalamic region The perforating branches arising from the posterior communicating artery may be divided into cisternal and parenchymal, although classification is impossible because of unusual variations in the course of these branches (Fig 8)

As the thalamoperforate artery is usually superimposed on the cerebellar or other arteries in the a p vertebral angiogram, only the lateral view was



Fig 13 Stenosis of Sylvian duct produc ng dila tat on of third vent cle and stretch g of paren chym l part of thalamoperforate artery (arrow)



F g 14 Stretch ng and forward and downward d splacement of parenchymal part of thalamo-perforate artery in pinealoma (arro)



Fig 15 Tu nour ar sing f om the quadr gem nal plate Stretch ng and forward displacement of th lamope forate artery (arrow)



Fig 16 Inf ltrat ng tumour in thalamus Irreg ularity of thalamoperforate rtery (arrow) and pathologic vessels

suitable for study and proved to be particularly informative (Fig 9) Minor movements of the head or poor contrast filling may however produce blurring of the artery The transitional portion between its cisternal and parenchymal parts lies in a straight line as seen at autopsy an appearance characteristic enough to allow easy differentiation of the two parts

The branches arising from the posterior communicating artery, visible in a vertebral angiogram in a quarter of 60 cases, are commonly observed in young

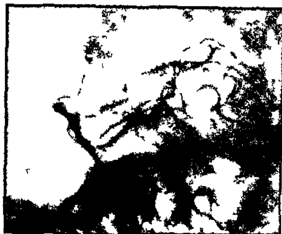


Fig 17 Backward displacement of basilar artery in clival tumour



Fig 18 Hemangioblastoma of cerebellum Stretching of superior cerebellar artery signs of angioma and slight stretching and upward and forward displacement of all parts of thalamo perforate artery

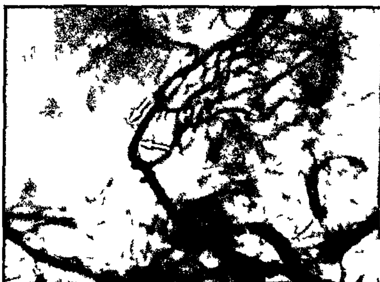


Fig 19 Cerebellopontine angle tumour Upward displacement of superior cerebellar artery posterior cerebral artery and cisternal part of thalamoperforate artery

subjects (Fig 10) Filling of these arteries is readily obtained by bilateral carotid compression during angiography (Fig 11)

Influence of tumours on the thalamoperforate artery The thalamoperforate artery is displaced and deformed in most cases of space occupying lesions arising in the deep cerebral region around the thalamus and midbrain or in the posterior fossa Fig 12 shows that the artery is stretched and displaced backwards by a

craniopharyngioma which is distended posteriorly The parenchymal part of the artery is seen to be stretched but no change in the cisternal part is evident in a case of dilatation of the third ventricle, these appearances were believed to be due to the dilatation of the third ventricle caused by stenosis of the Sylvian duct (Fig 13) Stretching and displacement forwards and downwards of the thalamoperforate artery are also evident in its parenchymal part with no changes in its cisternal part in a case of pinealoma in Fig 14 Stretching and forward displacement of the thalamoperforate artery occurred in a case of a tumour arising in the quadrigeminal plate (Fig 15) A tumour infiltrating the thalamus has caused irregularity of the thalamoperforate artery in Fig 16 Backward displacement of the thalamoperforate artery without stretching and deformity is evident in a case of a clival tumour in which the basilar artery is also displaced to the rear (Fig 17) In a case with a cerebellar tumour the thalamoperforate artery is displaced slightly upwards and forwards in all its parts but stretching is not marked (Fig 18) Fourteen out of 17 cases of cerebellar tumour were found to present these changes Slight upward displacement of the cisternal part of the thalamoperforate artery with slight stretching of its parenchymal part was present in a case of a cerebellopontine angle tumour (Fig 19) These findings were observed in 9 out of 10 cases of this condition

The importance of performing vertebral angiography in the diagnosis of deep seated lesions thus becomes apparent It would appear that arteriography of the thalamoperforate artery provides additional useful information in the study of intracranial lesions and adds a great deal to the knowledge of the vascular patterns that may be encountered in various conditions

Acknowledgement

This study was supported by a Research Grant from the Waksman Foundation of Japan

SUMMARY

A review is presented of the roentgen anatomical correlations of the vascular patterns of the small arteries particularly the thalamoperforate artery arising from the posterior part of the circle of Willis and effects caused by tumours

ZUSAMMENFASSUNG

Es wird eine Übersicht über die Röntgenanatomie der kleinen Arterien gegeben Im besonderen wird über die Art thalamoperforata die vom rückwärtigen Abschnitt des Circulus Willisi entspringt und ihre Beeinflussung durch Tumore berichtet

RÉSUMÉ

Etude des corrélations radio-anatomiques des petites artères issues de la partie postérieure du cercle de Willis et en particulier l'artère thalamo-perforée et des *modifications causées* par les tumeurs

REFERENCES

ANDERSEN P E The lenticulo striate arteries and their diagnostic value A preliminary report Acta radiol 50 (1958), 84

BEEVOR C E The cerebral arterial supply Brain 30 (1907) 403

ECKER A The normal cerebral angiogram Charles C Thomas Springfield Ill 1951

GALLOWAY J R and GREITZ T *The medial and lateral choroid arteries An anatomic and* roentgenographic study Acta radiol 53 (1960) 353

HAYMAKER W Handbuch der speziellen pathologischen Anatomie und Histologie (Henke-Lubarsch) Springer Verlag Berlin Gottingen Heidelberg 1957

HEUBNER A Zur Topographie der Ernährungsgebiete der einzelnen Hirnarterien Zbl med Wiss 52 (1872) 817

JOHANSON C The central veins and deep dural sinuses of the brain An anatomical and angiographic study Acta radiol Suppl (1954) 107

KODAMA Y Atlas of human anatomy Vol V Kanehara-shuppan Tokyo Japan 1956

KRAYENBUHL H und RICHTER H R Die zerebrale Angiographie Georg Thieme Verlag Stuttgart 1952

LINDBLOM K A roentgenographic study of the vascular channels of the skull Acta radiol Suppl (1936) 30

LINDENBERG R Handbuch der speziellen pathologischen Anatomie und Histologie (Henke Lubarsch) Springer Verlag Berlin Gottingen Heidelberg 1957

SJOGREN S E The anterior choroidal artery Acta radiol 46 (1956) 143

SUZUKI M Studies on the distribution of the basal branches of human cerebral arteries (Japanese) The Sapporo Medical Journal 19 (1961) 307

TESTUT L Traité d anatomie humaine Gaston Doin & Cie Paris 1929

WESTBERG G *The recurrent artery of Heubner and the arteries of the central ganglia* Acta radiol Diagnosis (1963) 949

FROM THE DEPARTMENT OF RADIOLOGY, ADDENBROOKE'S HOSPITAL (NEW SITE)
HILLS ROAD CAMBRIDGE, ENGLAND

RADIOLOGICAL INVESTIGATION OF GLOMUS JUGULARE TUMOURS

by

T DESMOND HAWKINS

The clinical and radiological features of glomus jugulare tumours have been widely recognised and reported since the original suggestion by ROSENWASSER in 1945 that his case of a carotid body tumour of the middle ear and mastoid might have originated in the glomus jugulare

A review of 316 case histories in the English literature showed that in 42 % there was no report of a roentgen examination (ALFORD & GUILFORD 1962) Even in some of the more recently reported cases the part that radiology can play in the investigations of these tumours has not been fully exploited

Glomus jugulare tumours are histologically similar to tumours of the carotid body but have their origin in the small or microscopic glomus bodies in or beneath the petrous bone These bodies occur most frequently in the adventitia of the jugular bulb on the cochlear promontory closely related to the tympanic branch of glossopharyngeus as it passes through the canal between the jugular fossa and the middle ear, and along the auricular branch of the vagus nerve (GUILD 1953) Tumours may arise in any of these bodies their clinical manifestation differing with their site of origin direction of growth and stage at which they are first detected The emphasis in this paper is on

RÉSUMÉ

Étude des corrélations radio anatomiques des petites artères issues de la partie postérieure du cercle de Willis et en particulier l'artère thalamo perforée et des modifications causées par les tumeurs

REFERENCES

ANDERSEN P E The lenticulo striate arteries and their diagnostic value A preliminary report Acta radiol 50 (1958) 84

BELLOR C F The cerebral arterial supply Brain 30 (1907) 403

ECKER A The normal cerebral angiogram Charles C Thomas Springfield Ill 1951

GALLOWAY J R and GREITZ T The medial and lateral choroid arteries An anatomic and roentgenographic study Acta radiol 53 (1960) 353

HAYMAKER W Handbuch der speziellen pathologischen Anatomie und Histologie (Henke-Lubarsch) Springer Verlag Berlin Gottingen Heidelberg 1957

HEUBNER A Zur Topographie der Ernährungsgebiete der einzelnen Hirnarterien Zbl med Wiss 52 (1872), 817

JOHANSON C The central veins and deep dural sinuses of the brain An anatomical and angiographic study Acta radiol Suppl (1954) 107

KODAMA Y Atlas of human anatomy Vol V Kanehara shuppan Tokyo Japan 1956

KRAYENBÜHL H und RICHTER H R Die zerebrale Angiographie Georg Thieme Verlag Stuttgart 1952

LINDBLOM K A roentgenographic study of the vascular channels of the skull Acta radiol Suppl (1936) 30

LINDENBERG R Handbuch der speziellen pathologischen Anatomie und Histologie (Henke Lubarsch) Springer Verlag Berlin Gottingen Heidelberg 1957

SJOGREN S E The anterior choroidal artery Acta radiol 46 (1956) 143

SUZUKI M Studies on the distribution of the basal branches of human cerebral arteries (Japanese) The Sapporo Medical Journal 19 (1961) 307

TESTUT L Traité d'anatomie humaine Gaston Doin & Cie Paris 1929

WESTBERG G The recurrent artery of Heubner and the arteries of the central ganglia Acta radiol Diagnosis (1963) 949

FROM THE DEPARTMENT OF RADIOLOGY ADDENBROOKE'S HOSPITAL (NEW SITE)
HILLS ROAD CAMBRIDGE ENGLAND

RADIOLOGICAL INVESTIGATION OF GLOMUS JUGULARE TUMOURS

by

T DESMOND HAWKINS

The clinical and radiological features of glomus jugulare tumours have been widely recognised and reported since the original suggestion by ROSENWASSER in 1945 that his case of a carotid body tumour of the middle ear and mastoid might have originated in the glomus jugulare

A review of 316 case histories in the English literature showed that in 42 % there was no report of a roentgen examination (ALFORD & GUILFORD 1962) Even in some of the more recently reported cases the part that radiology can play in the investigations of these tumours has not been fully exploited

Glomus jugulare tumours are histologically similar to tumours of the carotid body but have their origin in the small or microscopic glomus bodies in or beneath the petrous bone These bodies occur most frequently in the adventitia of the jugular bulb on the cochlear promontory closely related to the tympanic branch of glossopharyngeus as it passes through the canal between the jugular fossa and the middle ear and along the auricular branch of the vagus nerve (GUILD 1953) Tumours may arise in any of these bodies their clinical manifestation differing with their site of origin direction of growth and stage at which they are first detected The emphasis in this paper is on



Fig. 1. Tumour arising in the right jugular fossa. Enlargement of the right jugular fossa and adjacent bone destruction visible in the conventional semi-axial view (top) but better shown in the a.p. tomograms.

those tumours which produce neurological symptoms and signs rather than those which present primarily as otological problems.

The commonest neurological symptoms are those due to unilateral 9th, 10th, 11th and 12th cranial nerve palsies caused by a tumour growing in the jugular foramen. The middle ear is often involved, producing deafness,

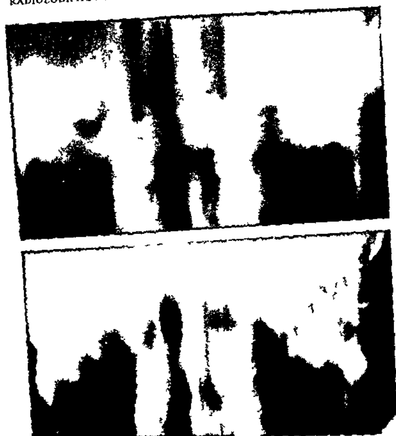


Fig 2 No m l ar tero-poste or tomogram (upper view) for co nparison with the al normal tom gram below Righ side l tumour causing bone destruction ar n l the jugular fo sa and foramen ar d al n the jugular tube cle ante ri r condyla canal and infero med al part of the pet ous bone (below)

tinnitus and facial palsy and a sanguineous discharge will occur if the tumour protrudes through the tympanic membrane or invades the external auditory canal Occasionally the presenting features are those of a posterior fossa tumour but careful clinical assessment will usually reveal an as ociated jugular fo ramen syndrome Two patients in the author s experience suffered a sub arach noid haemorrhage in one it was the presenting symptom It is those patients in whom neurological symptoms predominate or precede the otological which are a diagnostic challenge to the radiologist

The diagnostic radiologist s responsibility in the investigation and treatment of glomus jugulare tumours is fourfold



Fig 3 a) Normal oblique tomogram with the head turned 15° to the opposite side b) Oblique tomogram of patient shown in fig 2 demonstrating more clearly the destructive bone changes in the jugular tubercle and anterior condylar canal

1 To establish or confirm the diagnosis, especially in those cases which present primarily as neurological problems This should prevent precipitate neuro surgical exploration of an essentially non operable tumour and thus avoid the occasionally fatal haemorrhagic sequelae

2 To determine the site and size of the tumour This is not only to assess the field size for radiotherapy but to help decide on the need for prophylactic ventriculo cisternostomy before commencing treatment in cases with raised *intra cranial pressure*

3 To exclude other neoplasms involving the petrous bone and the presence of primary or secondary neoplasms elsewhere

4 To assess the results of treatment

These objectives can be achieved only by utilising all the available neuro radiological techniques

Conventional radiography The bone changes are frequently diagnostic in themselves but do not show the size of the tumour Standard views of the skull and special views of the petro mastoids should be taken, including tomograms Emphasis should be placed on the semi axial view and on the modified submento vertical view advocated by Eraso (1961) to show bone changes due to a tumour growing in the jugular foramen The foramina are



Fig 4 Glomus jugul re tumour A subtr ction p int of one of a lateral series of a common carot d angiogram The tumour ci culat on w th n and below the petrous bone is more clearly seen than on the original film

frequently unequal in size and there must be additional evidence of bone destruction for unilateral enlargement to be of significance Antero posterior tomograms of the petrous bone are usually informative (Fig 1) and oblique tomograms may also be instructive With the head turned 45° towards the unaffected side the jugular foramen and anterior part of the condylar canal are well seen (Fig 3a) If the head is turned to the affected side a good view is obtained of the whole of the anterior condylar canal and of the jugular fossa and foramen

As the tumour enlarges bone destruction may be seen in the jugular tubercle occipital condyle and condylar fossa (Fig 2 lower view and Fig 3b)

Anterior extension of the tumour may cause erosion in the basi occiput, temporo-mandibular joint or floor of the middle fossa Extension upwards will produce diffuse destructive changes in the petrous bone and elevation of the petrous ridge and tegmen tympani These changes have been described and illustrated in detail elsewhere (Cova et coll 1952 Holesh 1955 Kemp Harper 1957 Hawkins 1961)



a b

Fig 3 a) Normal oblique tomogram with the head turned 45° to the opposite side b) Oblique tomogram of patient shown in fig 2 demonstrating more clearly the destructive bone changes in the jugular tubercle and anterior condylar canal

1 To establish or confirm the diagnosis, especially in those cases which present primarily as neurological problems This should prevent precipitate neuro surgical exploration of an essentially non operable tumour and thus avoid the occasionally fatal haemorrhagic sequelae

2 To determine the site and size of the tumour This is not only to assess the field size for radiotherapy but to help decide on the need for prophylactic ventriculo cisternostomy before commencing treatment in cases with raised intra cranial pressure

3 To exclude other neoplasms involving the petrous bone and the presence of primary or secondary neoplasms elsewhere

4 To assess the results of treatment

These objectives can be achieved only by utilising all the available neuro radiological techniques

Conventional radiography The bone changes are frequently diagnostic in themselves but do not show the size of the tumour Standard views of the skull and special views of the petro mastoids should be taken, including tomograms Emphasis should be placed on the semi axial view and on the modified submento vertical view advocated by ERASO (1961) to show bone changes due to a tumour growing in the jugular foramen The foramina are



Fig 4 Glomus jugulare tumour A subtraction print of one of a lateral series of a common carotid angiogram The tumour circulation within and below the petrous bone is more clearly seen than on the original film

frequently unequal in size and there must be additional evidence of bone destruction for unilateral enlargement to be of significance Antero posterior tomograms of the petrous bone are usually informative (Fig 1) and oblique tomograms may also be instructive With the head turned 45 towards the unaffected side the jugular foramen and anterior part of the condylar canal are well seen (Fig 3a) If the head is turned to the affected side a good view is obtained of the whole of the anterior condylar canal and of the jugular fossa and foramen

As the tumour enlarges bone destruction may be seen in the jugular tubercle occipital condyle and condylar fossa (Fig 2 lower view and Fig 3b)

Anterior extension of the tumour may cause erosion in the basi occiput, temporo-mandibular joint or floor of the middle fossa Extension upwards will produce diffuse destructive changes in the petrous bone and elevation of the petrous ridge and tegmen tympani These changes have been described and illustrated in detail elsewhere (Cova *et coll* 1952 Holesh 1955 Kemp Harper 1957 Hawkins 1961)



a b

Fig 3 a) Normal oblique tomogram with the head turned 45 to the opposite side b) Oblique tomogram of patient shown in fig 2 demonstrating more clearly the destructive bone changes in the jugular tubercle and anterior condylar canal

1 To establish or confirm the diagnosis, especially in those cases which present primarily as neurological problems This should prevent precipitate neuro surgical exploration of an essentially non operable tumour and thus avoid the occasionally fatal haemorrhagic sequelae

2 To determine the site and size of the tumour This is not only to assess the field size for radiotherapy but to help decide on the need for prophylactic ventriculo cisternostomy before commencing treatment in cases with raised intra cranial pressure

3 To exclude other neoplasms involving the petrous bone and the presence of primary or secondary neoplasms elsewhere

4 To assess the results of treatment

These objectives can be achieved only by utilising all the available neuro radiological techniques

Conventional radiography The bone changes are frequently diagnostic in themselves but do not show the size of the tumour Standard views of the skull and special views of the petro mastoids should be taken, including tomograms Emphasis should be placed on the semi axial view and on the modified submento vertical view advocated by LE ASO (1961) to show bone changes due to a tumour growing in the jugular foramen The foramina are



Fig 4 Glomus jugulare tumour A subtraction print of one of a lateral series of a common ca otid angiogram The tumour circulat on w thin and below the pet ous bone is more clea ly seen than on the orig nal film

frequently unequal in size and there must be additional evidence of bone destruction for unilateral enlargement to be of significance Antero posterior tomograms of the petrous bone are usually informative (Fig 1) and oblique tomograms may also be instructive With the head turned 45 towards the unaffected side the jugular foramen and anterior part of the condylar canal are well seen (Fig 3a) If the head is turned to the affected side a good view is obtained of the whole of the anterior condylar canal and of the jugular fossa and foramen

As the tumour enlarges bone destruction may be seen in the jugular tubercle occipital condyle and condylar fossa (Fig 2 lower view and Fig 3b) Anterior extension of the tumour may cause erosion in the basi occiput temporo mandibular joint or floor of the middle fossa Extension upwards will produce diffuse destructive changes in the petrous bone and elevation of the petrous ridge and tegmen tympani These changes have been described and illustrated in detail elsewhere (Cova et coll 1952 Holesh 1955 Kemp Harper 1957 Hawkins 1961)



a b

Fig 3 a) Normal oblique tomogram with the head turned 45 to the opposite side b) tomogram of patient shown in fig 2 demonstrating more clearly the destructive bone chan jugular tubercle and anterior condylar canal

1 To establish or confirm the diagnosis, especially in those cases present primarily as neurological problems This should prevent prec neuro surgical exploration of an essentially non operable tumour an avoid the occasionally fatal haemorrhagic sequelae

2 To determine the site and size of the tumour This is not only to the field size for radiotherapy but to help decide on the need for prophyl ventriculo cisternostomy before commencing treatment in cases with r intra cranial pressure

3 To exclude other neoplasms involving the petrous bone and the presence primary or secondary neoplasms elsewhere

4 To assess the results of treatment

These objectives can be achieved only by utilising all the available neuro radiological techniques

Conventional radiography The bone changes are frequently diagnostic in themselves but do not show the size of the tumour Standard views of the skull and special views of the petro mastoids should be taken, including tomograms Emphasis should be placed on the semi axial view and on the modified submento vertical view advocated by FRASO (1961) to show bone changes due to a tumour growing in the jugular foramen The foramina are



Fig 4 Glomus jugulare tumour A subtraction print of one of a late al series of a common carotid angiogram Th tumour circul tion within and below the petrous bone is more clearly seen than on the original film

frequently unequal in size and there must be additional evidence of bone destruction for unilateral enlargement to be of significance Antero posterior tomograms of the petrous bone are usually informative (Fig 1) and oblique tomograms may also be instructive With the head turned 45° towards the unaffected side the jugular foramen and anterior part of the condylar canal are well seen (Fig 3a) If the head is turned to the affected side a good view is obtained of the whole of the anterior condylar canal and of the jugular fossa and foramen

As the tumour enlarges bone destruction may be seen in the jugular tubercle occipital condyle and condylar fossa (Fig 2 lower view and Fig 3b) Anterior extension of the tumour may cause erosion in the basi occiput temporo mandibular joint or floor of the middle fossa Extension upwards will produce diffuse destructive changes in the petrous bone and elevation of the petrous ridge and tegmen tympani These changes have been described and illustrated in detail elsewhere (Cova et coll 1952 Holesh 1955 Kemp Harper 1957 Hawkins 1961)

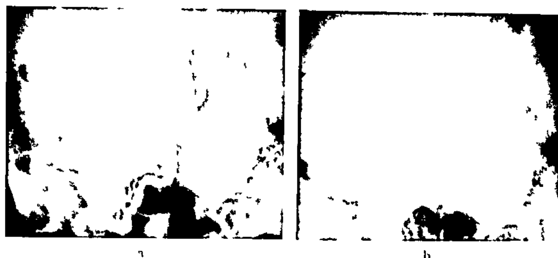


Fig. 5. Vertebral angiography, same patient as in fig. 4. a) Arterial phase. b) Venous phase. The intra-cranial part of the tumour is demonstrated but not the intra-osseous part. (The common carotid angiography failed to demonstrate the intra-cranial extension of the tumour.)

Angiography. It is important to perform angiography to try to demonstrate the position and size of these tumours which are normally highly vascular. The glomera from which they arise have a blood supply mainly from the tympanic branch of the ascending pharyngeal artery. The structures commonly invaded by the tumour are supplied by small tympanic and meningeal arteries which arise from branches of the external carotid artery, and similar small vessels arising from the internal carotid and vertebral arteries anastomose with them.

Hence common or external carotid angiography should be first performed in an attempt to demonstrate a pathologic tumour circulation. This will show either intense contrast filling of fine tumour vessels in and around the area of bone destruction or pooling of the contrast medium in vascular lakes within the tumour. An arterio-venous shunt may be seen communicating with the jugular vein or with the transverse sinus if the vein is obstructed by tumour (HOOPER 1955). The pathological tumour circulation is better seen if the subtraction method is used (Fig. 1).

Carotid angiography may however fail to demonstrate intra-cranial extension of the tumour. If this is suspected clinically, vertebral angiography should be performed since this part of the tumour may be fed by the vertebral artery or acquire a blood supply from the basilar artery (RIEMENSCHNEIDER et coll. 1953).

Fig. 5 illustrates the findings at vertebral angiography in the patient whose carotid angiogram is shown in Fig. 4. The intra-cranial part of the tumour



Fig 6 Myodil ventriculogram Right sided glomus jugulare tumour The intracranial extension of the tumour is not only distorting the brain stem but is invading the fourth ventricle The Myodil escaped from the ventricle through a false passage around the margin of the tumour



Fig 7 Right jugular phlebogram oblique projection demonstrating a large part of the tumour which otherwise would have been missed growing within and obstructing the upper part of the internal jugular vein

in the posterior fossa is visible but not the intrapetrous element The carotid angiogram showed the intra and infra petrous tumour but failed to demonstrate this intra cranial extension

Ventriculography Air or Myodil ventriculography are alternative methods of showing posterior fossa extension and although perhaps a less sensitive index of the size and position of the tumour may demonstrate brain stem distortion and the presence of an obstructive hydrocephalus Fig 6 shows one stage of a ventriculography with Myodil The intra cranial extension of a right sided tumour is not only producing brain stem distortion but is invading the fourth ventricle The Myodil escaped from the ventricle through a false passage around the margin of the tumour

Jugular phlebography Jugular phlebography has been little used in the investigation of these tumours There are at least four recorded cases where intraluminal extension into the internal jugular vein has been demonstrated at autopsy (TERRACOL & GUERRIER 1951, BICKERSTAFF & HOWELL 1953 HENSON

et coll 1953) Theoretically it would seem reasonable to suppose that tumours arising in the jugular fossa may produce extrinsic or intrinsic filling defects in the jugular vein by virtue of their close apposition to it In the one case where this radiological technique was used, a large intra luminal extension was demonstrated growing down from the jugular fossa and occluding this vessel (Fig 7) This part of the tumour was not shown by angiography and would have been missed had phlebography not been carried out

This investigation could be used in early cases to establish or confirm the diagnosis and in more advanced cases to demonstrate fully the extent of the tumour The relationship, if any, between intra luminal extension of a tumour and the occurrence of distant metastases might be clarified if this technique were more widely practised

Discussion

There should be little difficulty in correctly diagnosing the majority of cases of glomus jugulare tumour A polyp accessible to biopsy will be present in the external or middle ear in most patients This diagnostic method carries some risk from haemorrhage if the operator has not been forewarned of the probable nature of the polyp A radiological diagnosis can be arrived at in most cases, both otological and neurological in presentation, if a full examination of the skull is first carried out This is only part of the radiological responsibility, and angiography, ventriculography and phlebography may all be necessary to confirm the diagnosis and to obtain the information which should be available before commencing treatment The two conditions that are most likely to give rise to difficulty are meningiomas arising in the region of the sigmoid sinus, and tumours of the glomus intravagale (BERK 1961) If however, all the techniques available to the radiologist are made use of even these should not cause insuperable difficulties in differentiation from tumours of the glomus jugulare

Addendum in proofs

Since submission of this paper two publications (GEJROT 1964 GEJROT & LAURÉN 1964) have established the value of jugular phlebography in the diagnosis of glomus tumours in the jugular region Of 12 patients with glomus jugulare tumours examined by retrograde phlebography 9 had filling defects within or obstruction of the internal jugular vein at the base of the skull The three cases with negative findings were neurologically normal and it seems probable that in these instances the tumours had their origin in the tympanic bodies in the middle ear rather than in one of the glomera of the jugular bulb There was no reported evidence of distant metastases in those patients with intraluminal extension of the tumour in the internal jugular vein

SUMMARY

The part that radiology can play in the investigation of glomus jugulare tumours has not always been fully exploited The importance of radiological investigation of patients presenting primarily as neurological problems is emphasised Some of the results of investigation of these tumours are described and illustrated

ZUSAMMENFASSUNG

Die Moglichkeiten die die Radiologie bei der Untersuchung von Tumoren des Glomus jugulare bietet sind nicht immer voll ausgenutzt worden Die Wichtigkeit der Rontgenuntersuchung von Patienten mit primar neurologischen Problemen wird hervorgehoben Einige Untersuchungsresultate dieser Tumoren werden beschrieben und illustriert

RÉSUMÉ

On n a pas toujours exploité a fond les possibilites de la radiologie pour le diagnostic des tumeurs du glomus jugulaire L auteur insiste sur l importance de l examen radiologique pour des malades qui se présentent au premier abord comme des cas neurologiques Il décrit et donne en exemple les résultats d examens de ces tumeurs

REFERENCES

Alford B B and Guilford F R A comprehensive study of tumours of the glomus jugulare Laryngoscope 72 (1962) 765

Berk M E Chemodectoma of the glomus intravagale A case report and review Clin Radiol 12 (1961) 219

Bickerstaff E R and Howell J S The neurological importance of tumours of the glomus jugulare Brain 76 (1953) 576

Cova I L Meda P and Nicelli A F I tumori glomica timpano-giugulari Arch ital Otol 63 (1952) 568

Fraso S J Roentgen and clinical diagnosis of glomus jugulare tumours Radiology 77 (1961) 252

Gejrot T Jugular syndrome Acta Otolaryng 57 (1964) 450

— and Laurén T Retrograde jugulargraphy in diagnosis of glomus tumours in the jugular region Ibid 57 (1964) 131

Guild S R The glomus jugulare a non-chromaffin paraganglion in man Ann Otol St Louis) 62 (1953) 1 045

Hawkins T D Glomus jugulare and carotid body tumours Clin Radiol 12 (1961) 199

Henson R A Crawford J V and Cavanagh J B Tumours of the glomus jugulare J Neurol Neurosurg Psychiat 16 (1953) 127

Holfsh S Diagnosis of tumours of the glomus jugulare Lancet I (1955) 169

Hooper R S The glomus jugulare tumour Clinical and radiological features J Fac Radiol Lond 7 (1955) 77

KEMP HARPER R A Glomus jugulare tumours of the temporal bone J Fac Radiol (Lond) 8 (1957) 325

RIEMENSCHNEIDER P A , HOOPLE G D BREWER D , JONES D and ECKER A Roentgenographic diagnosis of tumours of the glomus jugularis Amer J Roentgenol 69 (1953) 59

ROSENWASSER H Carotid body tumour of the middle ear and mastoid Arch Otolaryng (Chicago) 41 (1945) 64

TERRACOL J and GUERRIER Y Les tumeurs du glomus jugulaire Montpellier med 41—2 (1951), 289

FROM THE DEPARTMENT OF RADIOLOGY COLUMBIA UNIVERSITY, COLLEGE OF PHYSICIANS AND SURGEONS AND THE RADIOLOGICAL SERVICE OF THE NEURO LOGICAL INSTITUTE COLUMBIA PRESBYTERIAN MEDICAL CENTER, NEW YORK U S A

HEMODYNAMIC RESPONSES IN THE CEREBRAL VESSELS TO ANGIOGRAPHIC CONTRAST MEDIA

by

SADEK K. HILAL

Extensive experimental investigations have been carried out in dogs to study the hemodynamic changes associated with the intra arterial injection of contrast media

Material and methods

The material consisted of 66 mongrel dogs weighing between 21 and 28 kg Eleven of these dogs represent techn cal failures and are not included in the reported results Twenty seven dogs were studied for the reactions due to the inj ction of contrast material in the femoral artery The changes associated with carotid injection were observed on the remaining 28 dogs Four of these 28 had craniotomy and middle cerebral artery catheterization Eight dogs provided the material for the determination of the least convulsive dose and finally the last 16 dogs of this group had exposure of the carotid artery and its branches in the neck for various experiments Intravenous nembutal was used for the induction and maintenance of anesthesia

The blood pressure was measured with the Statham strain gauge model P 23 DE These strain gauges have a small volume displacement and a high frequency response The flow was measured with the square wave electromagnetic flow meter manufactured by Avionics This unit has a frequency response of 150 cps and proved to have satisfactory long term stabili

KEMP HARPER R A Glomus jugulare tumours of the temporal bone J Fac Radiol (Lond) 8 (1957) 325
RIEMENSCHNEIDER P A HOOPLE G D BREWER D JONES D and ECKER A Roentgenographic diagnosis of tumours of the glomus jugularis Amer J Roentgenol 69 (1953) 59
ROSENWASSER H Carotid body tumour of the middle ear and mastoid Arch Otolaryng (Chicago) 41 (1945) 64
TERRACOL J and GUERRIER Y *Les tumeurs du glomus jugulaire Montpellier med* 41—2 (1951), 289

to prevent *reflux of contrast* medium in the common carotid Repeated injections were necessary to produce this effect Five ml of material were injected at a constant rate in a three second period After an interval of five seconds another 5 ml were injected *These 5 ml injections* were repeated until generalized seizures occurred Twenty minutes of recovery time were allowed and the same contrast was re injected using again multiple 5 ml injections *The last* injection however was reduced This scheme allowed the determination of the least *amount* producing convulsions The least convulsive dose of the other compounds was determined in the same way *Then the test was repeated on* all these materials in the same order as on the first run Two values were thus obtained for each contrast medium The basic order of injection of these contrast media was changed from dog to dog so that every compound had an equal chance to be the first injected Often the first seizure was difficult to initiate and a slightly larger dose than usual was required to produce the convulsion After this first seizure the animal responded consistently

Results

The hemodynamic changes resulting from the injection of contrast media in the carotid artery can be subdivided into two groups

I *Changes resulting from the mechanical interference with the blood flow*

This group of circulatory modifications occurs as a result of the injection of any liquid material in an artery and is not specific to contrast media Most of these changes *are discussed in great detail in* standard texts *on the physiology* of the circulation and the effect of vascular narrowing Only two aspects of these mechanical hemodynamic changes will be described here because of the general interest they stimulate and the relative lack of information available

Changes in the arterial pressure distal to the site of injection Outside of the jet of injection there is no increase in the peripheral blood pressure unless the needle or the catheter used has caused a significant stenosis across which a pressure gradient can be produced and maintained This fact has been tested experimentally by monitoring the pressure in the middle cerebral artery during a carotid injection No rise was observed when the injection catheter passed through the thyroid artery was clear from the lumen of the common carotid artery On the other hand when the catheter was threaded in the main artery for a distance of 1 to 2 cm *producing a 60 % narrowing a few mm Hg rise in* the peripheral pressure was observed

Changes in the blood flow in the artery injected The blood flow rate immediately proximal to the site of injection diminishes during the injection When contrast media are injected this decrease is roughly equal to the injection rate When this injection rate is faster than the local blood flow the contrast medium will run

ty Certain precautions were taken to assure accurate flow measurement These precautions include the choice of a properly fitting probe for each studied artery the repeated zero calibration by arterial occlusion the complete insulation of the animal and all attached instruments with rubber sheets and rubber binders and using *only one grounding point* This point was chosen to be the ground electrode of the flow probe For the measurement of the internal carotid flow two special probes were available having 1 0 mm and 0 75 mm diameter lumen respectively

Exposure and catheterization of various arteries in the head and neck The common carotid was exposed in the neck through a ventral incision A No 19 teflon catheter was threaded in a retrograde direction through the proximal segment of the cut thyroid artery until its tip was flush with the origin of this artery from the common carotid without projecting into the lumen of the main vessel to avoid impeding the flow through the common carotid The electromagnetic flow meter probe was positioned on the common carotid proximal to the origin of the thyroid artery so that the injected material did not pass within the field of the probe In certain cases the internal carotid was exposed for a distance of 2 to 3 cm beyond the bifurcation carefully avoiding excessive dissection of the carotid sinus area In these large dogs there was enough room to position the flow meter probe on the internal carotid

The lingual artery was exposed as distally as possible in the sub mandibular triangle The artery was cut and a catheter was introduced into the proximal segment for pressure recording and another catheter passed into the distal segment for contrast medium injection

In four dogs the middle cerebral artery branches were exposed through a parieto temporal craniotomy A No 28 teflon catheter was passed retrogradely into one of the middle cerebral artery branches on the surface of the brain as it exits from the Sylvian fissure When pressure was recorded special care was taken to keep this fine catheter full with saline to prevent damping of the pulse pressure with blood backing up in the catheter This catheter has been used also for the retrograde injection of contrast media for the study of the selective effect of these materials on the brain

Exposure and catheterization of the femoral artery and its branches One femoral artery was always exposed in the inguinal triangle and used for the retrograde catheterization of the abdominal aorta for systemic pressure monitoring The opposite femoral artery was exposed only in the experiments intended to study the reaction of the femoral arteries to contrast media The injection catheter was threaded retrogradely through one of the small muscular branches in the inguinal triangle without protruding into the lumen of the main artery The femoral flow was measured with the probe of the flow meter positioned proximal to the site of injection In this preparation the anterior tibial artery pressure was always monitored through a catheter passed retrogradely into this artery after its exposure on the flexor aspect of the ankle joint

Contrast media and injection technique Four contrast media were studied These were Sodium diatrizoate (Hypaque) Sodium iothalamate (Angio conray) Methyl glucamine diatrizoate (Renografin) and Meglumine iothalamate (Conray) The concentration of all these contrast media was adjusted with pyrogen free sterile distilled water so that the final content of iodine was 282 mg/ml A multiple speed constant rate injector was used At least five minutes recovery time was allowed to lapse before the injections were repeated

Determination of the least convulsive dose The contrast medium was injected in the internal carotid artery through a catheter threaded from the thyroid artery up the common carotid and into the internal carotid A ligature was tied around the internal carotid over the catheter

to prevent reflux of contrast medium in the common carotid Repeated injections were necessary to produce this effect Five ml of material were injected at a constant rate in a three second period After an interval of five seconds another 5 ml were injected These 5 ml injections were repeated until generalized seizures occurred Twenty minutes of recovery time were allowed and the same contrast was re injected using again multiple 5 ml injections The last injection however was reduced This scheme allowed the determination of the least amount producing convulsions The least convulsive dose of the other compounds was determined in the same way Then the test was repeated on all these materials in the same order as on the first run Two values were thus obtained for each contrast medium The basic order of injection of these contrast media was changed from dog to dog so that every compound had an equal chance to be the first injected Often the first seizure was difficult to initiate and a slightly larger dose than usual was required to produce the convulsion After this first seizure the animal responded consistently

Results

The hemodynamic changes resulting from the injection of contrast media in the carotid artery can be subdivided into two groups

I *Changes resulting from the mechanical interference with the blood flow*

This group of circulatory modifications occurs as a result of the injection of any liquid material in an artery and is not specific to contrast media Most of these changes are discussed in great detail in standard texts on the physiology of the circulation and the effect of vascular narrowing Only two aspects of these mechanical hemodynamic changes will be described here because of the general interest they stimulate and the relative lack of information available

Changes in the arterial pressure distal to the site of injection Outside of the jet of injection there is no increase in the peripheral blood pressure unless the needle or the catheter used has caused a significant stenosis across which a pressure gradient can be produced and maintained This fact has been tested experimentally by monitoring the pressure in the middle cerebral artery during a carotid injection No rise was observed when the injection catheter passed through the thyroid artery was clear from the lumen of the common carotid artery On the other hand when the catheter was threaded in the main artery for a distance of 1 to 2 cm producing a 60 % narrowing a few mm Hg rise in the peripheral pressure was observed

Changes in the blood flow in the artery injected The blood flow rate immediately proximal to the site of injection diminishes during the injection When contrast media are injected this decrease is roughly equal to the injection rate When this injection rate is faster than the local blood flow the contrast medium will run

ty Certain precautions were taken to assure accurate flow measurement These precautions include the choice of a properly fitting probe for each studied artery the repeated zero calibration by arterial occlusion the complete insulation of the animal and all attached instruments with rubber sheets and rubber binders and using only one grounding point This point was chosen to be the ground electrode of the flow probe For the measurement of the internal carotid flow two special probes were available having 1 0 mm and 0 75 mm diameter lumen respectively

Exposure and catheterization of various arteries in the head and neck The common carotid was exposed in the neck through a ventral incision A No 19 teflon catheter was threaded in a retrograde direction through the *proximal segment of the cut thyroid artery until its tip was flush* with the origin of this artery from the common carotid without projecting into the lumen of the main vessel to avoid impeding the flow through the common carotid The electromagnetic flow meter probe was positioned on the common carotid proximal to the origin of the thyroid artery so that the injected material did not pass within the field of the probe In certain cases the internal carotid was exposed for a distance of 2 to 3 cm beyond the bifurcation carefully avoiding excessive dissection of the carotid sinus area In these large dogs there was enough room to position the flow meter probe on the internal carotid

The lingual artery was exposed as distally as possible in the sub mandibular triangle The artery was cut and a catheter was introduced into the proximal segment for pressure recording and another catheter passed into the distal segment for contrast medium injection

In four dogs the middle cerebral artery branches were exposed through a parieto temporal craniotomy A No 28 teflon catheter was passed retrogradely into one of the middle cerebral artery branches on the surface of the brain as it exits from the Sylvian fissure When pressure was recorded special care was taken to keep this fine catheter full with saline to prevent damping of the pulse pressure with blood backing up in the catheter This catheter has been used also for the retrograde injection of contrast media for the study of the selective effect of these materials on the brain

Exposure and catheterization of the femoral artery and its branches One femoral artery was always exposed in the inguinal triangle and used for the retrograde catheterization of the abdominal aorta for systemic pressure monitoring The opposite femoral artery was exposed only in the experiments intended to study the reaction of the femoral arteries to contrast media The *injection catheter was threaded retrogradely through one of the small muscular branches* in the inguinal triangle without protruding into the lumen of the main artery The femoral flow was measured with the probe of the flow meter positioned proximal to the site of injection In this preparation the anterior tibial artery pressure was always monitored through a catheter passed *retrogradely into this artery after its exposure on the flexor aspect of the ankle joint*

Contrast media and injection technique Four contrast media were studied These were Sodium diatrizoate (Hypaque) Sodium iothalamate (Angio conray) Methyl glucamine diatrizoate (*Renografin*) and *Meglumine iothalamate (Conray)* The concentration of all these contrast media was adjusted with pyrogen free sterile distilled water so that the final content of iodine was 282 mg/ml A multiple speed constant rate injector was used At least five minutes recovery time was allowed to lapse before the injections were repeated

Determination of the least convulsive dose The contrast medium was injected in the internal carotid artery through a catheter threaded from the thyroid artery up the common carotid and into the internal carotid A ligature was tied around the internal carotid over the catheter

to prevent reflux of contrast medium in the common carotid Repeated injections were necessary to produce this effect Five ml of material were injected at a constant rate in a three second period After an interval of five seconds another 5 ml were injected These 5 ml injections were repeated until generalized seizures occurred Twenty minutes of recovery time were allowed and the same contrast was re injected using again multiple 5 ml injections The last injection however was reduced This scheme allowed the determination of the least amount producing convulsions The least convulsive dose of the other compounds was determined in the same way Then the test was repeated on all these materials in the same order as on the first run Two values were thus obtained for each contrast medium The basic order of injection of these contrast media was changed from dog to dog so that every compound had an equal chance to be the first injected Often the first seizure was difficult to initiate and a slightly larger dose than usual was required to produce the convulsion After this first seizure the animal responded consistently

Results

The hemodynamic changes resulting from the injection of contrast media in the carotid artery can be subdivided into two groups

I *Changes resulting from the mechanical interference with the blood flow*

This group of circulatory modifications occurs as a result of the injection of any liquid material in an artery and is not specific to contrast media Most of these changes are discussed in great detail in standard texts on the physiology of the circulation and the effect of vascular narrowing Only two aspects of these mechanical hemodynamic changes will be described here because of the general interest they stimulate and the relative lack of information available

Changes in the arterial pressure distal to the site of injection Outside of the jet of injection there is no increase in the peripheral blood pressure unless the needle or the catheter used has caused a significant stenosis across which a pressure gradient can be produced and maintained This fact has been tested experimentally by monitoring the pressure in the middle cerebral artery during a carotid injection No rise was observed when the injection catheter passed through the thyroid artery was clear from the lumen of the common carotid artery On the other hand when the catheter was threaded in the main artery for a distance of 1 to 2 cm producing a 60 % narrowing a few mm Hg rise in the peripheral pressure was observed

Changes in the blood flow in the artery injected The blood flow rate immediately proximal to the site of injection diminishes during the injection When contrast media are injected this decrease is roughly equal to the injection rate When this injection rate is faster than the local blood flow the contrast medium will run

ty. Certain precautions were taken to assure accurate flow measurement. These precautions include the choice of a properly fitting probe for each studied artery, the repeated zero calibration by arterial occlusion, the complete insulation of the animal and all attached instruments with rubber sheets and rubber binders and using only one grounding point. This point was chosen to be the ground electrode of the flow probe. For the measurement of the internal carotid flow, two special probes were available having 1.0 mm and 0.75 mm diameter lumen respectively.

Exposure and catheterization of various arteries in the head and neck. The common carotid was exposed in the neck through a ventral incision. A No. 19 teflon catheter was threaded in a retrograde direction through the proximal segment of the cut thyroid artery until its tip was flush with the origin of this artery from the common carotid without projecting into the lumen of the main vessel, to avoid impeding the flow through the common carotid. The electromagnetic flow meter probe was positioned on the common carotid proximal to the origin of the thyroid artery so that the injected material did not pass within the field of the probe. In certain cases the internal carotid was exposed for a distance of 2 to 3 cm beyond the bifurcation, carefully avoiding excessive dissection of the carotid sinus area. In these large dogs there was enough room to position the flow meter probe on the internal carotid.

The lingual artery was exposed as distally as possible in the sub mandibular triangle. The artery was cut and a catheter was introduced into the proximal segment for pressure recording and another catheter passed into the distal segment for contrast medium injection.

In four dogs the middle cerebral artery branches were exposed through a parieto temporal craniotomy. A No. 28 teflon catheter was passed retrogradely into one of the middle cerebral artery branches on the surface of the brain as it exits from the Sylvian fissure. When pressure was recorded special care was taken to keep this fine catheter full with saline to prevent damping of the pulse pressure with blood backing up in the catheter. This catheter has been used also for the retrograde injection of contrast media for the study of the selective effect of these materials on the brain.

Exposure and catheterization of the femoral artery and its branches. One femoral artery was always exposed in the inguinal triangle and used for the retrograde catheterization of the abdominal aorta for systemic pressure monitoring. The opposite femoral artery was exposed only in the experiments intended to study the reaction of the femoral arteries to contrast media. The injection catheter was threaded retrogradely through one of the small muscular branches in the inguinal triangle without protruding into the lumen of the main artery. The femoral flow was measured with the probe of the flow meter positioned proximal to the site of injection. In this preparation the anterior tibial artery pressure was always monitored through a catheter passed retrogradely into this artery after its exposure on the flexor aspect of the ankle joint.

Contrast media and injection technique. Four contrast media were studied. These were Sodium diatrizoate (Hypaque), Sodium iothalamate (Angio conray), Methyl glucamine diatrizoate (Renografin) and Meglumine iothalamate (Conray). The concentration of all these contrast media was adjusted with pyrogen free sterile distilled water so that the final content of iodine was 282 mg/ml. A multiple speed constant rate injector was used. At least five minutes recovery time was allowed to lapse before the injections were repeated.

Determination of the least convulsive dose. The contrast medium was injected in the internal carotid artery through a catheter threaded from the thyroid artery up the common carotid and into the internal carotid. A ligature was tied around the internal carotid over the catheter

to prevent reflux of contrast medium in the common carotid Repeated injections were necessary to produce this effect Five ml of material were injected at a constant rate in a three second period After an interval of five seconds another 5 ml were injected These 5 ml injections were repeated until generalized seizures occurred Twenty minutes of recovery time were allowed and the same contrast was re injected using *again multiple 5 ml injections* The last injection however was reduced This scheme allowed the determination of the least amount producing convulsions The least convulsive dose of the other compounds was determined in the same way Then the test was repeated on all these materials in the same order as on the first run Two values were thus obtained for each contrast medium The basic order of injection of these contrast media was changed from dog to dog so that every compound had an equal chance to be the first injected Often the first seizure was difficult to initiate and a slightly larger dose than usual was required to produce the convulsion After this first seizure the animal responded consistently

Results

The hemodynamic changes resulting from the injection of contrast media in the carotid artery can be subdivided into two groups

I *Changes resulting from the mechanical interference with the blood flow*

This group of circulatory modifications occurs as a result of the injection of any liquid material in an artery and is not specific to contrast media Most of these changes are discussed in great detail in standard texts on the physiology of the circulation and the effect of vascular narrowing Only two aspects of these mechanical hemodynamic changes will be described here because of the general interest they stimulate and the relative lack of information available

Changes in the arterial pressure distal to the site of injection Outside of the jet of injection there is no increase in the peripheral blood pressure unless the needle or the catheter used has caused a significant stenosis across which a pressure gradient can be produced and maintained This fact has been tested experimentally by monitoring the pressure in the middle cerebral artery during a carotid injection No rise was observed when the injection catheter passed through the thyroid artery was clear from the lumen of the common carotid artery On the other hand when the catheter was threaded in the main artery for a distance of 1 to 2 cm producing a 60 % *narrowing* a few mm Hg rise in the peripheral pressure was observed

Changes in the blood flow in the artery injected The blood flow rate immediately proximal to the site of injection diminishes during the injection When contrast media are injected this decrease is roughly equal to the injection rate When this injection rate is faster than the local blood flow the contrast medium will run

ty Certain precautions were taken to assure accurate flow measurement These precautions include the choice of a properly fitting probe for each studied artery the repeated zero calibration by arterial occlusion the complete insulation of the animal and all attached instruments with rubber sheets and rubber binders and using only one grounding point This point was chosen to be the ground electrode of the flow probe For the measurement of the internal carotid flow two special probes were available having 1 0 mm and 0 75 mm diameter lumen respectively

Exposure and catheterization of various arteries in the head and neck The common carotid was exposed in the neck through a ventral incision A No 19 teflon catheter was threaded in a retrograde direction through the proximal segment of the cut thyroid artery until its tip was flush with the origin of this artery from the common carotid without projecting into the lumen of the main vessel to avoid impeding the flow through the common carotid The electromagnetic flow meter probe was positioned on the common carotid proximal to the origin of the thyroid artery so that the injected material did not pass within the field of the probe In certain cases the internal carotid was exposed for a distance of 2 to 3 cm beyond the bifurcation carefully avoiding excessive dissection of the carotid sinus area In these large dogs there was enough room to position the flow meter probe on the internal carotid

The lingual artery was exposed as distally as possible in the sub mandibular triangle The artery was cut and a catheter was introduced into the proximal segment for pressure recording and another catheter passed into the distal segment for contrast medium injection

In four dogs the middle cerebral artery branches were exposed through a parieto temporal craniotomy A No 28 teflon catheter was passed retrogradely into one of the middle cerebral artery branches on the surface of the brain as it exits from the Sylvian fissure When pressure was recorded special care was taken to keep this fine catheter full with saline to prevent damping of the pulse pressure with blood backing up in the catheter This catheter has been used also for the retrograde injection of contrast media for the study of the selective effect of these materials on the brain

Exposure and catheterization of the femoral artery and its branches One femoral artery was always exposed in the inguinal triangle and used for the retrograde catheterization of the abdominal aorta for systemic pressure monitoring The opposite femoral artery was exposed only in the experiments intended to study the reaction of the femoral arteries to contrast media The injection catheter was threaded retrogradely through one of the small muscular branches in the inguinal triangle without protruding into the lumen of the main artery The femoral flow was measured with the probe of the flow meter positioned proximal to the site of injection In this preparation the anterior tibial artery pressure was always monitored through a catheter passed retrogradely into this artery after its exposure on the flexor aspect of the ankle joint

Contrast media and injection technique Four contrast media were studied These were Sodium diatrizoate (Hypaque) Sodium iothalamate (Angio conray) Methyl glucamine diatrizoate (Renografin) and Meglumine iothalamate (Conray) The concentration of all these contrast media was adjusted with pyrogen free sterile distilled water so that the final content of iodine was 282 mg/ml A multiple speed constant rate injector was used At least five minutes recovery time was allowed to lapse before the injections were repeated

Determination of the least convulsive dose The contrast medium was injected in the internal carotid artery through a catheter threaded from the thyroid artery up the common carotid and into the internal carotid A ligature was tied around the internal carotid over the catheter

where the electromagnetic flow meter probe was placed proximal to the injection site (Figs 2 and 3)

II *Changes resulting from the pharmacological activity of the contrast media*

The nature of the reactions to the contrast medium depends on the site of injection Although this presentation is concerned mostly with carotid angiography a brief description of the changes associated with femoral angiography will be given as a frame of reference

Femoral angiography The injection of a contrast agent in the femoral artery results in a marked increase of the blood flow rate to about 2 to 5 times the original rate (Fig 1) This local increase in flow is associated with a drop in both the diastolic arterial pressure and the pulse pressure distal to the site of injection These changes are due to severe vasodilation No variation is observed in the central systemic pressure This reaction can be produced by the injection of hypertonic solutions of sodium chloride glucose or urea and is not specific to contrast agents On the basis of this observation the author has developed a quantitative test for the measurement of the irritating effect of various contrast media compared with standard solutions of sodium chloride The area under the peak of the flow curve is measured accurately and is used as the basis of this comparison The detailed description of this test will be published separately

Carotid angiography These results are obtained from the analysis of 282 injections of contrast media and hypertonic solutions in 20 dogs Unlike the injections in the femoral artery carotid angiography produces important changes in the systemic blood pressure Another significant difference is the fact that the vasodilation seen in the femoral territory is only observed in the external carotid bed while the intracranial vessels do not show any vasodilatation

CHANGES IN THE CAROTID FLOW PATTERN a Common carotid flow When a contrast medium is injected in the common carotid artery the blood flow monitored proximal to the site of injection will show first a drop in the flow rate coinciding with the injection (Fig 2) This is followed by another drop which occurs during the first systemic hypotensive phase If this hypotension is severe the flow can actually drop to the zero level for one or two seconds as seen in Fig 10 with sodium diatrizoate The grave clinical significance of this marked decrease in the blood flow becomes more obvious when it is realized that it occurs in all four main cerebral trunks because it results from a central drop in pressure Following this drop there is a marked increase in the common carotid artery flow reaching 3 to 4 times the original rate in 15 to 25 seconds after the beginning of the injection to return to the base line in 100 to 130 seconds This increase in the common carotid flow rate is strictly due to vasodilation of the external carotid It is important to note

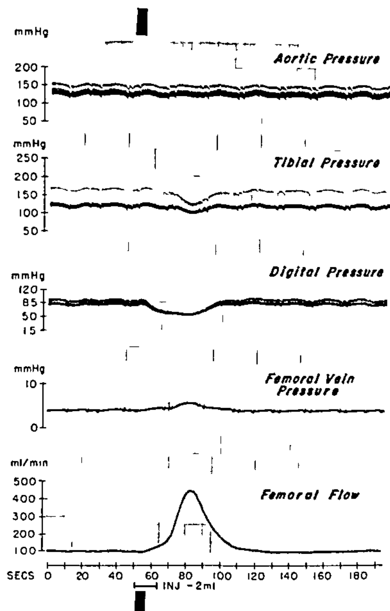


Fig 1 Injection of 2 ml of Hypaque 50 % in femoral artery of canine hind limb at rate of 10 ml per minute A 150 % increase in flow rate occurs No change seen in aortic pressure A drop in the tibial artery and digital artery pressure associated with a decrease of the pulse pressure is observed during the peak of increased flow Mild increase in femoral vein pressure

in a retrograde direction This is the usual clinical angiographic situation when peripheral vessels are studied The contrast medium is usually administered at twice the local flow rate for one second This decrease or reversal in the blood flow during the injection is seen on all the flow curves presented in this report

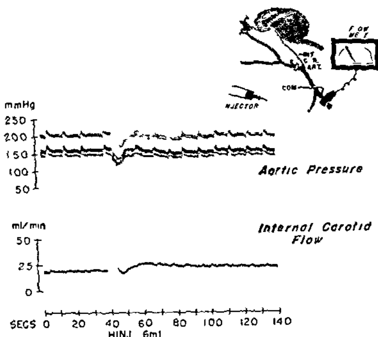


Fig 3 The external car tid is l gat d and the flow probe is posit oned on the common carotid Hypaque 50 is injected in the common ca otid The a rtic pressure curve shows first hypotensive phase followed by a hypertensive peak and then second hypotens ve phase The internal carotid flow curve shows reversal of the flow during the injection then a drop coincid ng with the first hypotens e ph se then a small rise during the hypertensive peak after which the flow curve comes down slowly to the original level This flow curve should be con pared with the common carot d flow in fig 2

combinations are shown in Figs 2, 3, 5 6 and 7 In the experiment shown in Fig 3 the injection was made in the common carotid artery as usual through the thyroid artery catheter and the flow probe was positioned on the common carotid proximal to the point of injection The external carotid was ligated A total of 58 injections in six dogs were studied Two to six ml were injected in 1 to 2 seconds The flow curve shows the initial drop in the flow rate due to the injection then a second drop which coincides with the fall in the systemic blood pressure and the bradycardia Then as the blood pressure rises slightly the internal carotid flow increases correspondingly The return of the flow curve to the original baseline usually follows the systemic blood pressure curve Often however this return is slightly delayed and shows a 10 % to 13 % increase of internal carotid flow that is not justified by changes in the

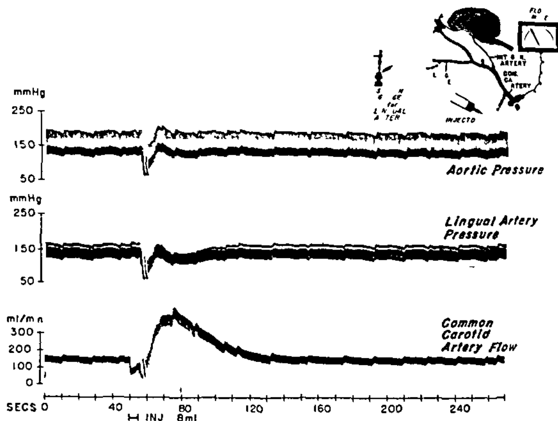


Fig 2 Injection of 8 ml of Hypaque 50 % in common carotid artery The aortic pressure shows first hypotensive phase with bradycardia to occur about 4 seconds after beginning of injection During this phase the diastolic pressure drops from 125 mm Hg to 65 mm Hg This is followed by a slight hypertensive peak where the systolic pressure reaches 210 mm Hg A mild second hypotensive phase follows where the diastolic pressure drops to 115 mm Hg from a baseline of 125 mm Hg Lingual artery pressure reflects changes seen in systemic blood pressure and shows an additional drop during peak of increased flow resulting from vasodilation Decrease in pulse pressure during this vasodilation The common carotid flow curve shows first the drop occurring during the injection followed by the drop due to the bradycardia and then a sharp increase resulting from the vasodilation of the external carotid vessels

that coinciding with the peak of the flow curve there is a drop in the lingual artery pressure associated with a decrease of the pulse pressure as seen in the vasodilation due to femoral angiography

b Internal carotid flow The study of the effect of the contrast media on the cerebral circulation is faced with two problems The first is the measurement of the cerebral flow, and the second is the delivery of the contrast agent specifically to the cerebral vessels without contaminating the external carotid circulation In the following set of experiments a variety of injection sites have been used and the blood flow has been monitored at various points The various

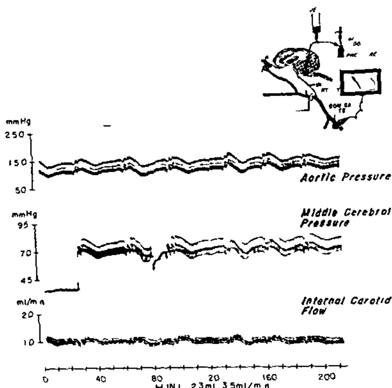


Fig 5 Sel ct ve nject on of Hypaque 50 n middle cerebral artery through the cathete used for pressure recording The middle cerebral pressure curv s rterrupted du ing the injection No change seen in the flow curve that would nd cate cereb al vasodilation No change in the systemic pressure

In order to simulate the clinical situation the experiment shown in Fig 7 was performed No artery was ligated and no craniotomy was performed The internal carotid flow was measured with a probe positioned on the internal carotid artery The curve shows a sharp peak occurring during the injection due to the flow of the material through the lumen of the probe This is followed by a marked decrease corresponding to the drop in the lingual artery pressure resulting from the vasodilation in the external carotid field *This drop in the* flow is due to redistribution of the blood from the unchanged intracranial vessels to the extremely dilated extracerebral vascular bed

Only during convulsions has the internal carotid flow been observed to increase to about twice the original level This is also associated with a drop in the middle cerebral artery pressure and narrowing of the middle cerebral



Fig 4 Roentgenogram of head of dog showing catheterization of a branch of the middle cerebral through a craniotomy with a retrograde injection of contrast material

systemic blood pressure This is thought to represent spillage of the contrast medium in the external carotid circulation Since the external carotid is ligated a portion of the internal carotid flow supplies the external carotid bed and this portion of the flow will increase in case of external carotid vasodilation *If the vertebral artery on the same side of the injection is* tied the internal carotid flow curve is seen to follow the systemic blood pressure more faithfully This is due to the fact that the internal carotid blood is then diverted mostly to the brain to compensate for the vertebral occlusion

To overcome the problem of external carotid contamination the contrast medium has been injected in the middle cerebral artery through a catheter threaded in a retrograde direction as shown in Figs 4, 5 and 6 The internal carotid flow does not show any change Also, if cerebral vasodilation had occurred a drop in the middle cerebral artery pressure would have been registered together with a narrowing of the pulse pressure The curves shown in Fig 6 demonstrate the result of middle cerebral artery injection given at a fast rate The drop in the middle cerebral artery pressure registered is not the result of cerebral vasodilation because it coincides in time and is equivalent in magnitude to the drop in the aortic pressure, and most important, there is no decrease *in the pulse pressure Twenty middle cerebral injections* have been performed in four dogs all of them showing similar results

larger doses of the contrast medium than those necessary to produce the vaso dilation The injection of 2 to 3 ml in one to two seconds is required to produce the reactions This represents an injection rate similar to the flow rate in the carotid artery resulting in exposing the receptors of these reflexes to the full concentration of the material injected The author has divided the disturbance in the systemic pressure into two phases

a The first hypotensive phase This phase (Figs 2 7 8) is characterized by a marked drop in the systemic blood pressure secondary to severe bradycardia which can even reach the point of asystole for two seconds (Fig 10) It starts about four seconds after the beginning of the injection, reaches its maximum by the fifth or seventh second and the normal heart rate is resumed by the twelfth to the fifteenth second after the beginning of the injection With the increase of the dose of contrast media the bradycardia will appear sooner last longer and will be more marked It is believed that the hypotension is secondary to the bradycardia since the systemic pressure curve in the time corresponding to the first hypotensive phase has shown bradycardia without hypotension while no hypotension has been seen without bradycardia Occasionally a hypertensive peak is seen at the beginning of the reaction during the first one or two cardiac beats after the onset of the bradycardia (Fig 7 Fig 8 on the 48 gm Na Cl/L tracing) This peak seems to result from a transient increase in the cardiac stroke volume associated with the bradycardia A similar peak can be seen at the end of this first hypotensive phase before the heart resumes its normal rate (Figs 2 7 and 9)

Bilateral vagotomy or atropine (0 5 mg/kg) will completely block this bradycardia indicating that the motor limb of this reflex is through the parasympathetic vagal supply to the heart The receptor limb of this reflex is more difficult to track Two types of experimental procedures have been conducted in order to determine the site of the receptors In the first procedure repeated injections are made in the internal carotid artery through a catheter threaded up the common carotid artery Only one minute is allowed to lapse between injections The bradycardia occurring with each injection diminishes in severity indicating that the sensitivity of the receptors involved is decreasing After three or four injections as the reflex becomes markedly attenuated, an additional injection is made in the common carotid artery A severe bradycardia is obtained indicating that a new set of receptors are being exposed This finding rules out the idea of one receptor centrally placed in the brain and points to a more diffuse distribution of these receptors in the carotid bed This experiment has been conducted on five dogs with identical results In the second experimental procedure the contrast agent is injected in a retrograde direction in the middle cerebral artery to give maximum exposure of the brain

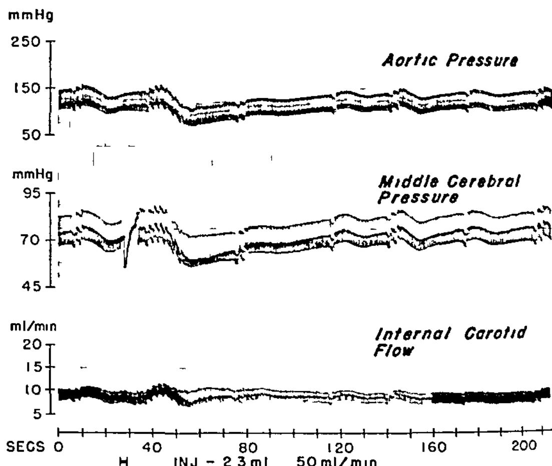


Fig 6 Same amount of material is injected in middle cerebral artery as in fig 5 A faster rate of injection is used however resulting in a better cerebral perfusion with the injected agent Only a pronounced second hypotensive phase is produced No bradycardia observed If a cerebral vasodilation had taken place a narrowing of the pulse pressure would have occurred No such narrowing is seen in the middle cerebral artery pressure tracing

pulse pressure This kind of change represents a true cerebral vasodilation as usually seen in other types of convulsions (12)

The vasodilation in the external carotid system, as in the femoral artery, can be produced by the injection of hypertonic solutions and does not represent a specific reaction to contrast media The doses required to produce the vasodilation in the external carotid circulation are small, 0 5 ml of contrast medium injected slowly in a five second period is sufficient to produce the reaction Since the flow in the canine common carotid is usually 80 ml/ min the receptors of this reflex seem to respond to a 13 fold dilution of the contrast medium

CHANGES IN THE SYSTEMIC PRESSURE These changes are produced by

larger doses of the contrast medium than those necessary to produce the vaso dilation The injection of 2 to 3 ml in one to two seconds is required to produce the reactions This represents an injection rate similar to the flow rate in the carotid artery resulting in exposing the receptors of these reflexes to the full concentration of the material injected The author has divided the disturbance in the systemic pressure into two phases

a The first hypotensive phase This phase (Figs 2 7 8) is characterized by a marked drop in the systemic blood pressure secondary to severe bradycardia which can even reach the point of asystole for two seconds (Fig 10) It starts about four seconds after the beginning of the injection reaches its maximum by the fifth or seventh second and the normal heart rate is resumed by the twelfth to the fifteenth second after the beginning of the injection With the increase of the dose of contrast media the bradycardia will appear sooner, last longer and will be more marked It is believed that the hypotension is secondary to the bradycardia since the systemic pressure curve in the time corresponding to the first hypotensive phase has shown bradycardia without hypotension while no hypotension has been seen without bradycardia Occasionally a hypertensive peak is seen at the beginning of the reaction during the first one or two cardiac beats after the onset of the bradycardia (Fig 7 Fig 8 on the 48 gm Na Cl/L tracing) This peak seems to result from a transient increase in the cardiac stroke volume associated with the bradycardia A similar peak can be seen at the end of this first hypotensive phase before the heart resumes its normal rate (Figs 2 7 and 9)

Bilateral vagotomy or atropine (0 5 mg/kg) will completely block this bradycardia indicating that the motor limb of this reflex is through the parasympathetic vagal supply to the heart The receptor limb of this reflex is more difficult to track Two types of experimental procedures have been conducted in order to determine the site of the receptors In the first procedure repeated injections are made in the internal carotid artery through a catheter threaded up the common carotid artery Only one minute is allowed to lapse between injections The bradycardia occurring with each injection diminishes in severity indicating that the sensitivity of the receptors involved is decreasing After three or four injections as the reflex becomes markedly attenuated an additional injection is made in the common carotid artery A severe bradycardia is obtained indicating that a new set of receptors are being exposed This finding rules out the idea of one receptor centrally placed in the brain and points to a more diffuse distribution of these receptors in the carotid bed This experiment has been conducted on five dogs with identical results In the second experimental procedure the contrast agent is injected in a retrograde direction in the middle cerebral artery to give maximum exposure of the brain

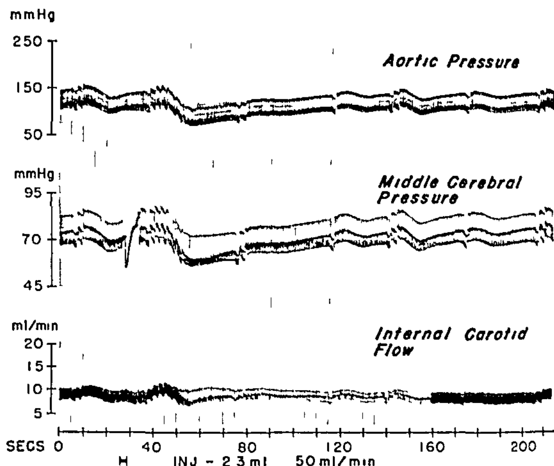


Fig. 6. Same amount of material is injected in middle cerebral artery as in fig. [illegible]. A faster rate of injection is used however, resulting in a better cerebral perfusion with the injected agent. Only a pronounced second hypotensive phase is produced. No bradycardia observed. If a cerebral vasodilation had taken place, a narrowing of the pulse pressure would have occurred. No such narrowing is seen in the middle cerebral artery pressure tracing.

pulse pressure. This kind of change represents a true cerebral vasodilation as usually seen in other types of convulsions (12).

The vasodilation in the external carotid system, as in the femoral artery, can be produced by the injection of hypertonic solutions and does not represent a specific reaction to contrast media. The doses required to produce the vasodilation in the external carotid circulation are small, 0.5 ml of contrast medium injected slowly in a five second period is sufficient to produce the reaction. Since the flow in the canine common carotid is usually 80 ml/min the receptors of this reflex seem to respond to a 13 fold dilution of the contrast medium.

CHANGES IN THE SYSTEMIC PRESSURE. These changes are produced by

larger doses of the contrast medium than those necessary to produce the vasodilation The injection of 2 to 3 ml in one to two seconds is required to produce the reactions This represents an injection rate similar to the flow rate in the carotid artery resulting in exposing the receptors of these reflexes to the full concentration of the material injected The author has divided the disturbance in the systemic pressure into two phases

1 The first hypotensive phase This phase (Figs 2 7 8) is characterized by a marked drop in the systemic blood pressure secondary to severe bradycardia which can even reach the point of asystole for two seconds (Fig 10) It starts about four seconds after the beginning of the injection reaches its maximum by the fifth or seventh second and the normal heart rate is resumed by the twelfth to the fifteenth second after the beginning of the injection With the increase of the dose of contrast media the bradycardia will appear sooner last longer, and will be more marked It is believed that the hypotension is secondary to the bradycardia since the systemic pressure curve in the time corresponding to the first hypotensive phase has shown bradycardia without hypotension while no hypotension has been seen without bradycardia Occasionally a hypertensive peak is seen at the beginning of the reaction during the first one or two cardiac beats after the onset of the bradycardia (Fig 7, Fig 8 on the 48 gm Na Cl/L tracing) This peak seems to result from a *transient* increase in the cardiac stroke volume associated with the bradycardia A similar peak can be seen at the end of this first hypotensive phase *before the heart* resumes its normal rate (Figs 2 7 and 9)

Bilateral vagotomy or atropine (0 5 mg/kg) will completely *block this* bradycardia indicating that the motor limb of this reflex is through the parasympathetic vagal supply to the heart *The receptor limb of* this reflex is more difficult to track Two types of experimental *procedures* have been conducted in order to determine the *site of the receptors* In the first procedure repeated injections are made in the internal carotid artery *through* a catheter threaded up the common carotid artery *Only one* minute is allowed to lapse between injections The bradycardia occurring *with each* injection diminishes in severity indicating that the sensitivity *of the receptors* involved is decreasing After three or four injections as the reflex *becomes markedly* attenuated an additional injection is made in the common *carotid* artery A severe bradycardia is obtained indicating that a new *set of* receptors are being exposed This finding rules out the idea of one *receptor centrally* placed in the brain and points to a more diffuse distribution *of these receptors* in the carotid bed This experiment has been conducted on five dogs with identical results In the *second* experimental procedure the contrast *agent is* injected in a retrograde *direction* in the middle cerebral artery to give maximum *exposure of* the brain

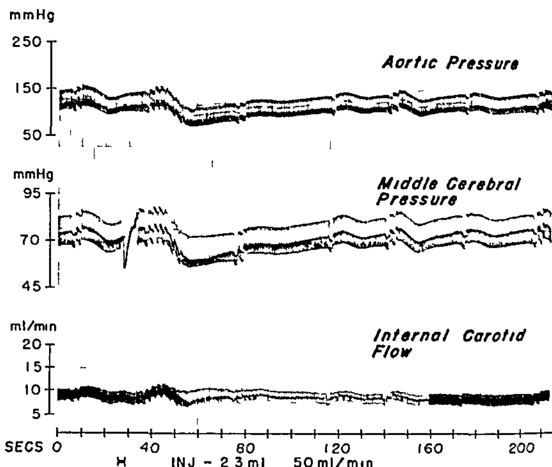


Fig 6 Same amount of material is injected in middle cerebral artery as in fig 5 A faster rate of injection is used however resulting in a better cerebral perfusion with the injected agent Only a pronounced second hypotensive phase is produced No bradycardia observed If a cerebral vasodilation had taken place a narrowing of the pulse pressure would have occurred No such narrowing is seen in the middle cerebral artery pressure tracing

pulse pressure This kind of change represents a true cerebral vasodilation as usually seen in other types of convulsions (12)

The vasodilation in the external carotid system, as in the femoral artery, can be produced by the injection of hypertonic solutions and does not represent a specific reaction to contrast media The doses required to produce the vaso dilation in the external carotid circulation are small, 0 5 ml of contrast medium injected slowly in a five second period is sufficient to produce the reaction Since the flow in the canine common carotid is usually 80 ml/ min *the receptors of this reflex seem to respond to a 13 fold dilution of the contrast medium*

CHANGES IN THE SYSTEMIC PRESSURE These changes are produced by

larger doses of the contrast medium than those necessary to produce the vaso dilation The injection of 2 to 3 ml in one to two seconds is required to produce the reactions This represents an injection rate similar to the flow rate in the carotid artery resulting in exposing the receptors of these reflexes to the full concentration of the material injected The author has divided the disturbance in the systemic pressure into two phases

a The first hypotensive phase This phase (Figs 2 7, 8) is characterized by a marked drop in the systemic blood pressure secondary to severe bradycardia which can even reach the point of asystole for two seconds (Fig 10) It starts about four seconds after the beginning of the injection reaches its maximum by the fifth or seventh second and the normal heart rate is resumed by the twelfth to the fifteenth second after the beginning of the injection With the increase of the dose of contrast media the bradycardia will appear sooner last longer and will be more marked It is believed that the hypotension is secondary to the bradycardia since the systemic pressure curve in the time corresponding to the first hypotensive phase has shown bradycardia without hypotension while no hypotension has been seen without bradycardia Occasionally a hypertensive peak is seen at the beginning of the reaction during the first one or two cardiac beats after the onset of the bradycardia (Fig 7 Fig 8 on the 48 gm Na Cl/L tracing) This peak seems to result from a transient increase in the cardiac stroke volume associated with the bradycardia A similar peak can be seen at the end of this first hypotensive phase before the heart resumes its normal rate (Figs 2 7 and 9)

Bilateral vagotomy or atropine (0 5 mg/kg) will completely block this bradycardia indicating that the motor limb of this reflex is through the parasympathetic vagal supply to the heart The receptor limb of this reflex is more difficult to track Two types of experimental procedures have been conducted in order to determine the site of the receptors In the first procedure repeated injections are made in the internal carotid artery through a catheter threaded up the common carotid artery Only one minute is allowed to lapse between injections The bradycardia occurring with each injection diminishes in severity indicating that the sensitivity of the receptors involved is decreasing After three or four injections as the reflex becomes markedly attenuated an additional injection is made in the common carotid artery A severe brady cardia is obtained indicating that a new set of receptors are being exposed This finding rules out the idea of one receptor centrally placed in the brain and points to a more diffuse distribution of these receptors in the carotid bed This experiment has been conducted on five dogs with identical results In the second experimental procedure the contrast agent is injected in a retrograde direction in the middle cerebral artery to give maximum exposure of the brain

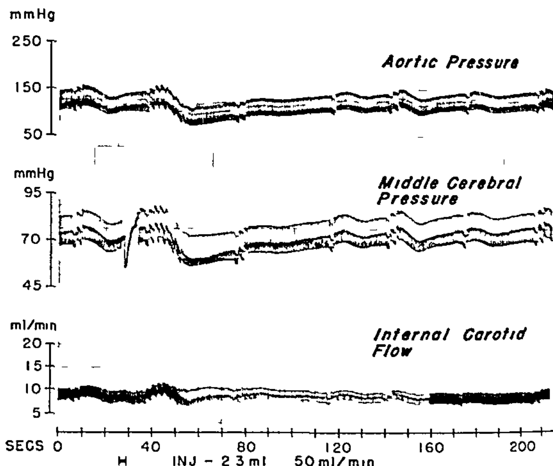


Fig 6 Same amount of material is injected in middle cerebral artery as in fig 5 A faster rate of injection is used however resulting in a better cerebral perfusion with the injected agent Only a pronounced second hypotensive phase is produced No bradycardia observed If a cerebral vasodilation had taken place a narrowing of the pulse pressure would have occurred No such narrowing is seen in the middle cerebral artery pressure tracing

pulse pressure This kind of change represents a true cerebral vasodilation as usually seen in other types of convulsions (12)

The vasodilation in the external carotid system, as in the femoral artery, can be produced by the injection of hypertonic solutions and does not represent a specific reaction to contrast media The doses required to produce the vasodilation in the external carotid circulation are small, 0 5 ml of contrast medium injected slowly in a five second period is sufficient to produce the reaction Since the flow in the canine common carotid is usually 80 ml/ min the receptors of this reflex seem to respond to a 13 fold dilution of the contrast medium

CHANGES IN THE SYSTEMIC PRESSURE These changes are produced by

larger doses of the contrast medium than those necessary to produce the vaso dilation The injection of 2 to 3 ml in one to two seconds is required to produce the reactions This represents an injection rate similar to the flow rate in the carotid artery resulting in exposing the receptors of these reflexes to the full concentration of the material injected The author has divided the disturbance in the systemic pressure into two phases

a The first hypotensive phase This phase (Figs 2 7, 8) is characterized by a marked drop in the systemic blood pre sure secondary to severe bradycardia which can even reach the point of asystole for two seconds (Fig 10) It starts about four seconds after the beginning of the injection reaches its maximum by the fifth or seventh second and the normal heart rate is resumed by the twelfth to the fifteenth second after the beginning of the injection With the increase of the dose of contrast media the bradycardia will appear sooner last longer, and will be more marked It is believed that the hypotension is secondary to the bradycardia since the systemic pressure curve in the time corresponding to the first hypotensive phase has shown bradycardia without hypotension while no hypotension has been seen without bradycardia Occasionally a hypertensive peak is seen at the beginning of the reaction during the first one or two cardiac beats after the onset of the bradycardia (Fig 7 Fig 8 on the 48 gm Na Cl/L tracing) This peak seems to result from a transient increase in the cardiac stroke volume associated with the bradycardia A similar peak can be seen at the end of this first hypotensive phase before the heart resumes its normal rate (Fig 2 7 and 9)

Bilateral vagotomy or atropine (0 5 mg/kg) will completely block this bradycardia indicating that the motor limb of this reflex is through the parasympathetic vagal supply to the heart The receptor limb of this reflex is more difficult to track Two types of experimental procedures have been conducted in order to determine the site of the receptors In the first procedure repeated injections are made in the internal carotid artery through a catheter threaded up the common carotid artery Only one minute is allowed to lapse between injections The bradycardia occurring with each injection diminishes in severity indicating that the sensitivity of the receptors involved is decreasing After three or four injections as the reflex becomes markedly attenuated an additional injection is made in the common carotid artery A severe bradycardia is obtained indicating that a new set of receptors are being exposed This finding rules out the idea of one receptor centrally placed in the brain and points to a more diffuse distribution of these receptors in the carotid bed This experiment has been conducted on five dogs with identical results In the second experimental procedure the contrast agent is injected in a retrograde direction in the middle cerebral artery to give maximum exposure of the brain

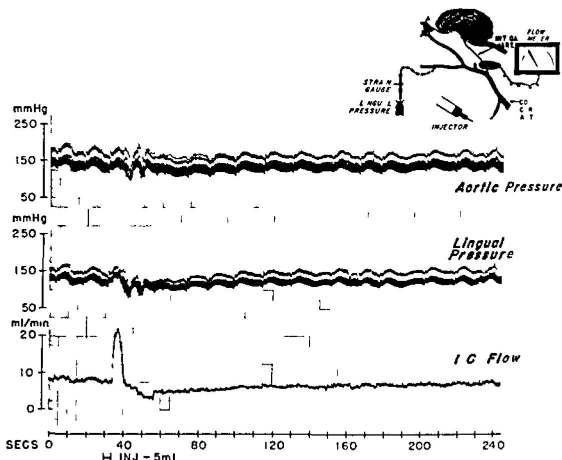


Fig 7 Changes in internal carotid flow due to common carotid injection of Hypaque 50 The two hypotensive phases are evident on the aortic pressure tracing separated by a hypertensive peak *The drop in the lingual artery pressure as evident in fig 2 coincides with the increase in the common* carotid flow On this tracing however the internal carotid flow shows a reduction during this same time which may be due to re distribution of the blood from the intra to the extracranial vessels

Injections are also made in the distal segment of the lingual artery where the contrast medium has no way to reach the brain except in extremely dilute form Three out of four dogs used showed no bradycardia with the middle cerebral artery injections while the fourth one showed a mild effect (Figs 5 and 6) The lingual artery injections on the other hand produced severe bradycardia in all of them (Fig 9) When a faster injection is made in the middle cerebral artery producing a more extensive exposure of the brain cen ters (Fig 6) hypotension without bradycardia results This represents the second hypotensive phase described below In the one dog where injection in the middle cerebral artery produced a mild bradycardia it is probable

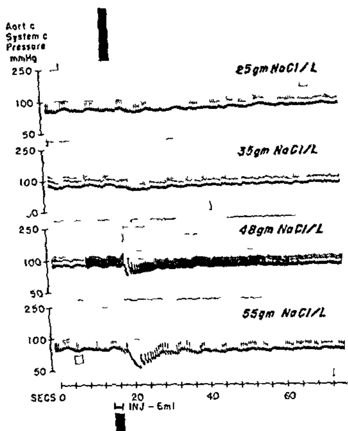


Fig 8 Disturbance of systemic pressure resulting from injection of hypertonic sodium chloride solutions in common carotid artery The higher concentrations produce more marked hypotension

that some of the contrast material reached the ophthalmic artery and stimulated receptors in the orbit These findings support the view that the receptors for this reflex are rather widely distributed in the extracerebral vessels

The first hypotensive phase can be produced by the injection of hypertonic Na Cl solution and hypertonic glucose The higher concentrations produce more marked reactions (Fig 8) Consequently it is assumed that this reflex is not specific to contrast agents and results from a variety of irritating stimuli No detailed quantitative study of this reaction has been made for the purpose of comparing various contrast media with standard hypertonic saline solutions It was found however in our experiments as in those conducted by FISCHER &

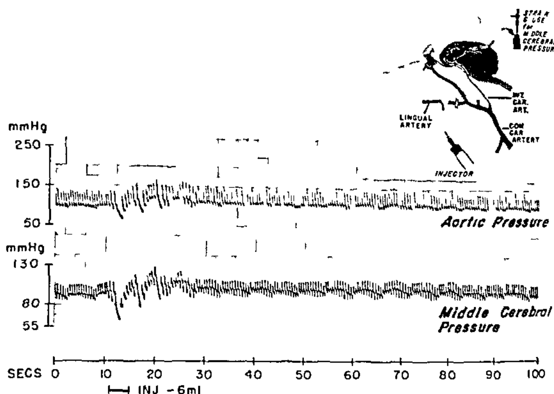


Fig. 9. Tracings of the aortic and middle cerebral artery pressure indicating that the first hypotensive phase and the bradycardia can be produced by *injection of 6 ml Hypaque in the distal segment of the lingual artery*.

Eckstein (3) that the relative severity of the reactions produced by various contrast media was fairly consistent in all 16 dogs. The findings were as follows: Sodium diatrizoate (Hypaque) produced the severest reaction, sodium iothalamate (Angio Conray) a similar reaction to that of Hypaque or slightly milder, methylglucamine diatrizoate (Renografin) a reaction much milder than Angio Conray, and meglumine iothalamate (Conray) the mildest reaction of all.

b. The second hypotensive phase. This phase (Figs. 2, 7, 6, 10) is characterized by hypotension without bradycardia. It starts 17 seconds after the injection and reaches its lowest level at about 30 seconds. The blood pressure returns to normal at about 45—55 seconds. The drop is about 15 mm of mercury in the diastolic pressure. This reflex is less constant than the first hypotensive phase and usually requires a larger dose of contrast medium. It happened in 13 out of 16 dogs and was more obvious when the contrast medium was injected for *4 seconds at about twice the rate of flow (a total of 6—8 ml in the* common carotid artery). This hypotension is produced when the injection is

direct effect of the contrast medium on the brain centers This reaction is also nonspecific in nature and can be caused by the injection of hypertonic solutions, Meglumine iothalamate (Conray) produced the mildest reaction (Fig 10)

CONVULSIVE EFFECT OF CONTRAST MEDIA Injection of contrast media in the internal carotid artery produces convulsions This effect is discussed in this report because it is associated with cerebral hemodynamic changes as described earlier These convulsions have been divided into two phases which seem to coincide chronologically with the two hypotensive phases described earlier

a The phase of muscular spasm Spasm of the neck muscles and of the body occur on the same side as the injection resulting in bending of the head and of the body to the side of the injection This spasm occurs whether the injection is made in the common carotid or in either one of its branches The injection of hypertonic solutions will produce it It occurs during the first hypotensive phase and bears the same chronological relation to the injection as the bradycardia Also as with the first hypotensive phase sodium diatrizoate produced the severest spasm while the meglumine iothalamate (Conray) produced the mildest reactions Because of the ipsilateral nature of the spasm and the injection this reflex does not seem to be due to the effect of the injected material on the brain but rather the result of a local irritating effect

b The phase of generalized convulsion These convulsions start as the muscular spasm is subsiding They are characterized by generalized bilateral seizures involving both upper and lower limbs Their duration is variable and depends on the type of contrast medium injected When severe they can remain for as long as two minutes In the mild cases only one generalized myoclonic contraction may be seen

These convulsions occur only when contrast medium is injected in the internal carotid artery in large quantities Of all the previously described toxic effects these convulsions are the only reaction that is specific to contrast media and cannot be produced by the injection of hypertonic solutions

Occasionally these convulsions can be caused by a single injection however multiple injections are usually required as mentioned earlier It appears that the seizures are the result of the damage to the blood brain barrier with the probable extravasation of minute amounts of contrast media The first injection damages the blood brain barrier and the material injected afterwards extravasates The least convulsive dose of the various contrast media tested in 8 dogs is as follows Sodium diatrizoate (Hypaque) 10—12 ml sodium iothalamate (Angio Conray) 11—13 ml methylglucamine diatrizoate (Renografin) 16—20 ml meglumine iothalamate (Conray) 25 ml or more

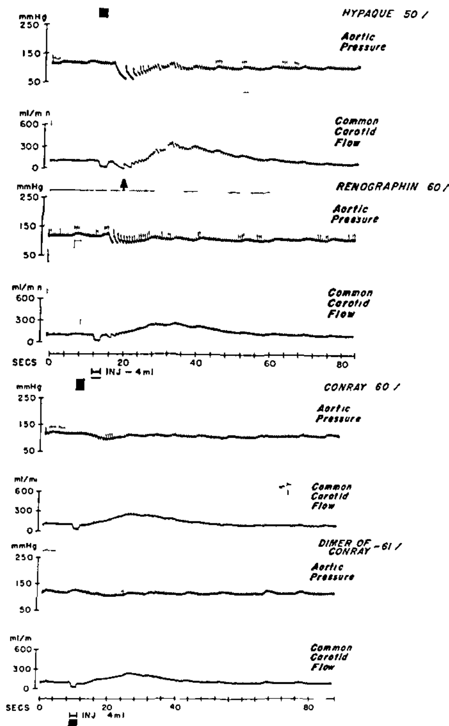


Fig 10 Comparative effect of various radiographic contrast media on systemic pressure and common carotid flow Arrow shows drop in common carotid flow to zero level after injection of Hypaque 50 Conray dimer shows least changes in systemic pressure and least vasodilation

Discussion

Because of the increasing frequency of the use of clinical angiography and ecause of the necessity to make this diagnostic procedure as safe as possible, umerous investigators have expended a great deal of effort to study the oxic effects associated with the injection of contrast media The few references hat are mentioned are only representative and by no means exhaustive The iscussion of the results presented in this work will be restricted to the changes ccurring in cerebral hemodynamics

Changes in the internal carotid flow The results reported here correspond to the ndings of SODERBERG & WECKMAN (14 7) who postulated a redistribution f the blood flow from the intra to the extracerebral vessels with a resultant lecreased pressure in the cerebral arteries

Many investigators used a Forbes window to observe the pial vessels during carotid angiography (2 4, 13) None of them however, measured the systemic blood pressure with a sufficiently fast responding monometer to detect the transient hypotension and to correlate it with the variation observed in the size of the pial vessels It is a well known fact that a sudden drop in the blood pressure causes a passive contraction of the pial vessels while a more sustained drop in the blood pressure causes dilation of these vessels (6) In carotid angiography both types of hypotensions occur and the interpretation of the results of Forbes window observation can only be accurately made in the light of a simultaneous adequate systemic blood pressure recording

The results reported here seem to contradict the flow measurements made by KÅGSTROM et coll (8 9) who found an increase in the internal carotid flow in the dog It is difficult to detect exactly the reason for this discrepancy It appears however that the technique they used which involves vascular surgery with multiple arterial anastomoses performed on relatively minute vessels could affect in an unpredictable manner the normal hemodynamics The angiographic demonstration presented in their work does not rule out the contamination of the external carotid bed with a small amount of contrast media especially that the collateral communication between the internal and external carotid in the dog is known to be very significant Should this contamination happen an increase in the flow will definitely be recorded As mentioned earlier vasodilation can result from very small amounts of dilute contrast agent

The two hypotensive phases Variations in the blood pressure and heart rate resulting from carotid angiography have been reported many times (3, 5 10 11) The present author has shown that a marked significant decrease in the carotid flow rate occurs when the bradycardia is severe The demonstration

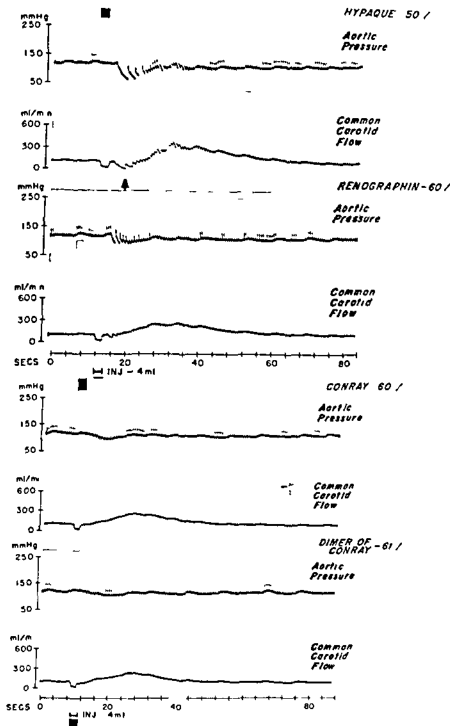


Fig. 10. Comparative effect of various radiographic contrast media on systemic pressure and common carotid flow. Arrow shows drop in common carotid flow to zero level after injection of Hypaque 50 %. Conray dimer shows least changes in systemic pressure and least vasodilation.

Discussion

Because of the increasing frequency of the use of clinical angiography and because of the necessity to make this diagnostic procedure as safe as possible numerous investigators have expended a great deal of effort to study the toxic effects associated with the injection of contrast media The few references that are mentioned are only representative and by no means exhaustive The discussion of the results presented in this work will be restricted to the changes occurring in cerebral hemodynamics

Changes in the internal carotid flow The results reported here correspond to the findings of SODERBERG & WECKMAN (14 7) who postulated a redistribution of the blood flow from the intra to the extracerebral vessels with a resultant decreased pressure in the cerebral arteries

Many investigators used a Forbes window to observe the pial vessels during carotid angiography (2 4 13) None of them however, measured the systemic blood pressure with a sufficiently fast responding monometer to detect the transient hypotension and to correlate it with the variation observed in the size of the pial vessels It is a well known fact that a sudden drop in the blood pressure causes a passive contraction of the pial vessels while a more sustained drop in the blood pressure causes dilation of these vessels (6) In carotid angio graphy both types of hypotensions occur and the interpretation of the results of Forbes window observation can only be accurately made in the light of a simultaneous adequate systemic blood pressure recording

The results reported here seem to contradict the flow measurements made by KAGSTROM et coll (8 9) who found an increase in the internal carotid flow in the dog It is difficult to detect exactly the reason for this discrepancy It appears however that the technique they used which involves vascular surgery with multiple arterial anastomoses performed on relatively minute vessels could affect in an unpredictable manner the normal hemodynamics The angiographic demonstration presented in their work does not rule out the contamination of the external carotid bed with a small amount of contrast media especially that the collateral communication between the internal and external carotid in the dog is known to be very significant Should this contamination happen an increase in the flow will definitely be recorded As mentioned earlier vasodilation can result from very small amounts of dilute contrast agent

The two hypotensive phases Variations in the blood pressure and heart rate resulting from carotid angiography have been reported many times (3, 5 10 11) The present author has shown that a marked significant decrease in the carotid flow rate occurs when the bradycardia is severe The demonstration

of this transient but significant change in the flow rate was made possible because of the use of the electromagnetic flow meter

The two different components of the hypotension are described for the first time here The identification of the different receptors involved in each case was possible because of the use of the selective injection technique where the cerebral vessels and the extracranial vessels have been injected separately

The convulsive effect Convulsions have been observed as a result of carotid angiography (1, 7, 15) The muscular spasm seen in the laboratory experiments is also observed in a mild form in patients who very frequently bend their head slightly towards the side of the injection The generalized seizures are seen only occasionally in the clinical situation They seem to result from the effect of the contrast medium on the brain after the damage to the blood brain barrier The inability of hypertonic chloride solution and hypertonic glucose to produce these convulsions can be explained in two ways either they are unable to damage the blood brain barrier, or they are unable to produce seizures even after the vascular permeability has been damaged

It is interesting to note that the phase of muscular spasm coincides with the bradycardia and the phase of generalized convulsions coincides with the second hypotensive phase The first two result from the irritating effect of the contrast medium on the extracerebral structures, and the second two result from the effect of the contrast agent on the central nervous system In addition to the chronological coincidence, the severity of the reactions in each group usually also shows a good correlation, i e when the bradycardia is severe the spasm is also severe The same applies for the convulsions and the second hypotensive phase

The determination of the least convulsive dose of the contrast media is an in vivo study of their effect on the blood brain barrier in a test that does not necessitate the sacrifice of the animal and thus offers the possibility of comparing various compounds on the same dog The success of the author in obtaining repeatable results with this test is probably due to the fact that the internal carotid is ligated around the catheter Injections of large volumes of contrast medium in this arrangement will cause the irrigation of the whole brain with the medium since the increased pressure in the vessel injected will cause a temporary stop of the blood flow from the other main arterial trunks supplying the circle of Willis

Development of a new contrast agent From the results presented here it appears that the hypertonicity of the recently developed contrast media plays an important part in their toxicity The chemical activity of these compounds has been considerably reduced in the last decade since the introduction of the

diatrizoate preparations followed by their methylglucamine salts and most recently the iothalamate group The hypertonicity has been shown to be important in producing the bradycardia and in producing the external carotid vasodilation, both reactions act together to reduce the internal carotid flow Pursuing this line of thinking the author tested the irritating effect of a new contrast agent that has a reduced tonicity for the same iodine content This contrast agent has been prepared by the combination of two molecules of the iothalamate product by a four carbon chain link This bisadditive has been called for convenience, the Conray dimer The number of molecules for the same amount of iodine is thus diminished resulting in the reduction of the osmolar activity of the solution As seen from the tracings of Fig 10 this compound is less irritating than any available opaque agent according to these experiments It produces less vasodilation less systemic hypotension and no convulsions could be produced after the injection of quantities as large as 35 ml in the internal carotid artery The muscular spasm can hardly be noticed These findings indicate that this compound would be very suitable for carotid angiography Clinical use however should await more extensive experimental testing

Conclusions

The results can be summarized as follows

1 Contrast media when injected intra arterially will cause vasodilation of the peripheral somatic vessels but not of the cerebral vessels In the case of a common carotid injection this *difference in effect* causes a decrease of the internal carotid flow in favor of the dilated external carotid bed

2 The injection in the carotid artery will produce two phases of hypotension The first one is due to severe bradycardia resulting from the irritation of receptors in the extra cerebral carotid vessels and the second phase of hypotension is the result of the effect of the contrast media on the brain centers

3 The convulsive effects of the contrast media have been studied and the author developed a technique to measure the least convulsive dose of the contrast agents This test is felt by the author to represent an in vivo study of the damage to the blood brain barrier

4 The importance of the hypertonicity of the contrast media as a significant contributing factor to their toxicity has been demonstrated The author has developed another test for the quantitative evaluation of the irritating effect of the contrast media based on the comparison with standard hypertonic sodium chloride solutions in producing peripheral vasodilation

5 A new contrast medium with a reduced toxicity for the same iodine content has been developed and tested with very encouraging results

Acknowledgements

The author wishes to express his gratitude for the valuable advice and suggestions of Dr Juan M Taveras during the conduction of this study The investigation was supported in part by Grant 5 RO 1 HE 08785 of the National Institute of Health and in part by Grant 5 T 1 NB 5298 05 of the National Institute of Neurological Diseases and Blindness

SUMMARY

The hemodynamic changes in the cerebral vessels associated with the intra arterial injection of contrast media at angiography have been studied in dogs

ZUSAMMENFASSUNG

Die hämodynamischen Veränderungen der zerebralen Gefässe bei Angiographie mit intraarterieller Kontrastinjektionen wurden an Hunden studiert

RÉSUMÉ

L auteur a étudié sur des chiens les modifications hémodynamiques créées dans les vaisseaux cérébraux par l injection intra artérielle de moyen de contraste au cours de l angiographie

REFERENCES

1 ABBOTT K H GAY J R and GOODALL R J Clinical complications of cerebral angiography J Neurosurg 9 (1952) 258
2 BROWNE K M and STERN W E Experimental observations concerning cerebral angiography Arch Neurol Psychiat 71 (1954) 477
3 FISCHER H W and ECKSTEIN J W Comparison of cerebral angiographic contrast by their circulatory effects Amer J Roentgenol 86 (1961) 166
4 FOLTZ E L THOMAS L B and WARD A A JR Effects of intracarotid diodrast J Neurosurg 9 (1952) 68
5 GREITZ T A *Radiological study of brain circulation by rapid serial angiography of carotid artery* Acta radiol (1956) Suppl 140
6 GURDJIAN E S and THOMAS L M Human pial circulation Arch Neurol 5 (1961) 111
7 INGVAR D H and SODERBERG U Cerebral vasomotor tone and EEG during injection of umbradil Acta radiol 47 (1957) 185
8 KÅGSTROM E LINDGREN P and TORNELL G Changes in cerebral circulation during carotid angiography with sodium acetrizoate (Triurol) and sodium diatrizoate (Hypaque) Acta radiol 50 (1958) 151
9 — — — Circulatory disturbances during cerebral angiography Experimental evaluation of certain contrast media Acta radiol 54 (1960) 3

10 LINDGREN P Carotid angiography with tri iodobenzoic acid derivatives comparative experimental study of effects on systemic circulation in cats Acta radiol 51 (1959) 353
11 — and TORNELL G Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (Triurol) Acta radiol 50 (1958) 160
12 MEYER J S and GOTOH F Interaction of cerebral hemodynamics and metabolism Neurology 4 (1961) 46
13 SCHMIDT H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media 44 (1955) 100
14 SODERBERG U and WECKMAN N Blood pressure changes in cerebral arteries during carotid angiography with Umbradil Acta radiol 50 (1958) 317
15 WHITELEATHER J E and DESAUSSURE R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956) 537

Acknowledgements

The author wishes to express his gratitude for the valuable advice and suggestions of Dr. Juan M. Taveras during the conduction of this study. The investigation was supported in part by Grant 5 RO 1 HE 08785 of the National Institute of Health and in part by Grant 5 T1 NB 5298 05 of the National Institute of Neurological Diseases and Blindness.

SUMMARY

The hemodynamic changes in the cerebral vessels associated with the intra-arterial injection of contrast media at angiography have been studied in dogs.

ZUSAMMENFASSUNG

Die hämodynamischen Veränderungen der zerebralen Gefässe bei Angiographie mit intraarterieller Kontrastinjektionen wurden an Hunden studiert.

RÉSUMÉ

L'auteur a étudié sur des chiens les modifications hémodynamiques créées dans les vaisseaux cérébraux par l'injection intra-artérielle de moyen de contraste au cours de l'angiographie.

REFERENCES

1. ABBOTT, K. H., GAY, J. R. and GOODALL, R. J.: Clinical complications of cerebral angiography. J. Neurosurg. 9 (1952), 258.
2. BROWNE, K. M. and STERN, W. E.: Experimental observations concerning cerebral angiography. Arch. Neurol. Psychiat. 71 (1954), 477.
3. FISCHER, H. W. and ECKSTEIN, J. W.: Comparison of cerebral angiographic contrast by their circulatory effects. Amer. J. Roentgenol. 86 (1961), 166.
4. FOLTZ, E. L., THOMAS, L. B. and WARD, A. A. JR.: Effects of intracarotid diodrast. J. Neurosurg. 9 (1952), 68.
5. GREITZ, T. A.: Radiological study of brain circulation by rapid serial angiography of carotid artery. Acta radiol. (1956), Suppl. 140.
6. GURDJIAN, E. S. and THOMAS, L. M.: Human pial circulation. Arch. Neurol. 5 (1961), 111.
7. INGVAR, D. H. and SODERBERG, U.: Cerebral vasomotor tone and EEG during injection of umbradil. Acta radiol. 47 (1957), 185.
8. KÅGSTROM, E., LINDGREN, P. and TORNELL, G.: *Changes in cerebral circulation during* carotid angiography with sodium acetrizoate (Triurol) and sodium diatrizoate (Hypaque). Acta radiol. 50 (1958), 151.
9. — — —: Circulatory disturbances during cerebral angiography. Experimental evaluation of certain contrast media. Acta radiol. 54 (1960), 3.

10 LINDGREN P Carotid angiography with tri iodobenzoic acid derivatives comparative experimental study of effects on systemic circulation in cats Acta radiol 51 (1959) 353
11 — and TORNELL G Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (Triurol) Acta radiol 50 (1958) 160
12 MEYER J S and GOTOH F Interaction of cerebral hemodynamics and metabolism Neurology 4 (1961) 46
13 SCHMIDT H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media 44 (1955) 100
14 SODERBERG U and WECKMAN N Blood pressure changes in cerebral arteries during carotid angiography with Umbradil Acta radiol 50 (1958) 317
15 WHITELEATHER J E and DESAUSSURE R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956) 537

Acknowledgements

The author wishes to express his gratitude for the valuable advice and suggestions of Dr Juan M Taveras during the conduction of this study The investigation was supported in part by Grant 5 RO 1 HE 08785 of the National Institute of Health and in part by Grant 5 T 1 NB 5298 05 of the National Institute of Neurological Diseases and Blindness

SUMMARY

The hemodynamic changes in the cerebral vessels associated with the intra arterial injection of contrast media at angiography have been studied in dogs

ZUSAMMENFASSUNG

Die hämodynamischen Veränderungen der zerebralen Gefässe bei Angiographie mit *intraarterieller Kontrastinjektionen wurden an Hunden studiert*

RÉSUMÉ

L auteur a étudié sur des chiens les modifications hémodynamiques créées dans les vaisseaux cérébraux par l injection intra artérielle de moyen de contraste au cours de l angiographie

REFERENCES

1 Abbott K H Gay J R and Goodall R J Clinical complications of cerebral angiography J Neurosurg 9 (1952) 258
2 Browne K M and Stern W E Experimental observations concerning cerebral angiography Arch Neurol Psychiat 71 (1954) 477
3 Fischer H W and Eckstein J W Comparison of cerebral angiographic contrast by their circulatory effects Amer J Roentgenol 86 (1961) 166
4 Foltz E L Thomas L B and Ward A A Jr Effects of intracarotid diodrast J Neurosurg 9 (1952) 68
5 Greitz T A Radiological study of brain circulation by rapid serial angiography of carotid artery *Acta radiol (1956) Suppl 140*
6 Gurdjian E S and Thomas L M Human pial circulation Arch Neurol 5 (1961) 111
7 Ingvar D H and Soderberg U Cerebral vasomotor tone and EEG during injection of umbradil Acta radiol 47 (1957) 185
8 Kågstrom E Lindgren P and Tornell G Changes in cerebral circulation during carotid angiography with sodium acetrizoate (Triurol) and sodium diatrizoate (Hypaque) Acta radiol 50 (1958) 151
9 — — — Circulatory disturbances during cerebral angiography Experimental evaluation of certain contrast media Acta radiol 54 (1960) 3

10 LINDGREN P Carotid angiography with tri iodobenzoic acid derivatives comparative experimental study of effects on systemic circulation in cats Acta radiol 51 (1959) 353

11 — and TORNELL G Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (Triurol) Acta radiol 50 (1958) 160

12 MEYER J S and GOTOH F Interaction of cerebral hemodynamics and metabolism Neurology 4 (1961) 46

13 SCHMIDT H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media 44 (1955) 100

14 SODERBERG U and WECKMAN N Blood pressure changes in cerebral arteries during carotid angiography with Umbradil Acta radiol 50 (1958) 317

15 WHITELEATHER J E and DESAUSSURE R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956) 537

Acknowledgements

The author wishes to express his gratitude for the valuable advice and suggestions of Dr Juan M Taveras during the conduction of this study The investigation was supported in part by Grant 5 RO 1 HE 08785 of the National Institute of Health and in part by Grant 5 T 1 NB 5298 05 of the National Institute of Neurological Diseases and Blindness

SUMMARY

The hemodynamic changes in the cerebral vessels associated with the intra arterial injection of contrast media at angiography have been studied in dogs

ZUSAMMENFASSUNG

Die hämodynamischen Veränderungen der zerebralen Gefässe bei Angiographie mit intraarterieller Kontrastinjektionen wurden an Hunden studiert

RÉSUMÉ

L'auteur a étudié sur des chiens les modifications hémodynamiques créées dans les vaisseaux cérébraux par l'injection intra artérielle de moyen de contraste au cours de l'angiographie

REFERENCES

1 Abbott K H Chan J R and Goodall R J Clinical complications of cerebral angiography J Neurosurg 9 (1952) 258
2 Browne K M and Stern W E Experimental observations concerning cerebral angiography Arch Neurol Psychiat 71 (1954) 477
3 Fischer H W and Eckstein J W Comparison of cerebral angiographic contrast by their circulatory effects Amer J Roentgenol 86 (1961) 166
4 Foltz E L Thomas L B and Ward A A Jr Effects of intracarotid diodrast J Neurosurg 9 (1952) 68
5 Greitz T A Radiological study of brain circulation by rapid serial angiography of carotid artery Acta radiol (1956) Suppl 140
6 Gurdjian E S and Thomas L M Human pial circulation Arch Neurol 5 (1961) 111
7 Ingvar D H and Soderberg U Cerebral vasomotor tone and EEG during injection of umbradil Acta radiol 47 (1957) 185
8 Kågström E Lindgren P and Törnell G Changes in cerebral circulation during carotid angiography with sodium acetrizoate (Triurol) and sodium diatrizoate (Hypaque) Acta radiol 50 (1958) 151
9 — — — Circulatory disturbances during cerebral angiography Experimental evaluation of certain contrast media Acta radiol 54 (1960) 3

10 Lindgren P Carotid angiography with tri iodobenzoic acid derivatives comparative experimental study of effects on systemic circulation in cats Acta radiol 51 (1959) 353
11 — and Tornell G Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (Triurol) Acta radiol 50 (1958) 160
12 Meyer J S and Gotoh F Interaction of cerebral hemodynamics and metabolism Neurology 4 (1961) 46
13 Schmidt H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media 44 (1955) 100
14 Soderberg U and Weckman N Blood pressure changes in cerebral arteries during carotid angiography with Umbradil Acta radiol 50 (1958) 317
15 Whiteleather J E and DeSaussure R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956) 537

the
ious

ne
his
s-

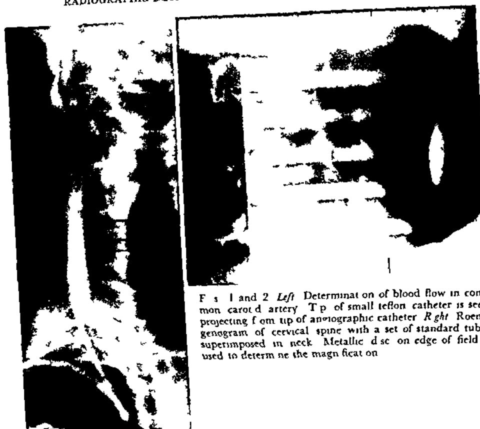
FROM THE DEPARTMENT OF RADIOLOGY, COLUMBIA UNIVERSITY COLLEGE OF PHYSICIANS AND SURGEONS, AND THE RADIOLOGICAL SERVICE OF THE NEUROLOGICAL INSTITUTE, COLUMBIA PRESBYTERIAN MEDICAL CENTER, NEW YORK, AND FROM THE DEPARTMENTS OF NEUROLOGY AND RADIOLOGY OF THE UNIVERSITY OF MINNESOTA, MINNEAPOLIS, MINNESOTA, U S A

DETERMINATION OF THE CAROTID AND REGIONAL CEREBRAL BLOOD FLOW BY A RADIOGRAPHIC TECHNIQUE

by

SADEK K. HILAL, JOSEPH A. RESCH and KURT AMPLATZ

The radiographic method for the determination of the blood flow in individual carotid arteries presented here is an indicator dilution technique. The indicator is a contrast medium injected at a known constant rate in the artery of interest. The concentration of the contrast medium distal to the site of injection is a function of the blood flow rate in the artery. Higher flow rates will cause more dilution of the medium and consequently a roentgenogram of the vessel will show little optical contrast between the artery and the background because of the dilution of the contrast material. On the other hand, a small flow rate will cause a lesser dilution of the indicator and a larger optical contrast will be observed between the vessel and its background. In the method presented here the optical density is accurately measured with a densitometer using a 40 micra light beam. The dilution of the contrast medium is determined by comparing the measured optical contrast of the image of the artery against *its background with the optical contrast of a set of standard* tubes containing a known concentration of the contrast medium used. The



F s 1 and 2 *Left* Determinat on of blood flow in com mon carot d artery T p of small teflon catheter is seen projecting f om tip of angiographic catheter *R ght* Roentgenogram of cervical spine with a set of standard tubes superimposed in neck Metallic d sc on edge of field is used to determ ne the magn ficat on

flow is calculated from the dilution of the contrast agent and from the known rate of injection according to the Hamilton Stewart formula

The determination of the regional flow will be briefly mentioned at the end of this report since it is still in the preliminary stages

Methods

No detailed mathematical procedure will be described here as this is the subject of a separate publication Only a brief description of the various technical aspects involved is presented

The sensitometric curve of the radiographic film is first made The relative exposure necessary to give the various shades of gray is thus determined This first step is necessary for the calibration of the type of film used and the processing technique Since the automatic processor is used this sensitometric curve is determined only once every few months For the blood flow determination



Fig. 3. Narrowing of the internal carotid artery by 60 %. Flow measurements indicated a 52 % reduction as compared with opposite side.

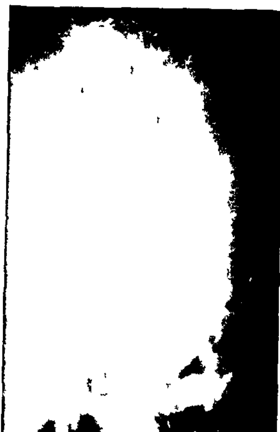


Fig. 4. Carotid angiogram. Occlusion of left middle cerebral artery.

*the optical density of the roentgenogram taken during the constant rate in*jection of the contrast medium is measured in two points: one just outside the limits of the image of the artery on the film, and the second in the middle of the artery. The relative exposure corresponding to each density is determined from the sensitometric curve obtained above. Since the image of the artery on the film is lighter than its background, the relative exposure of the film corresponding to the artery is always less than the relative exposure of the background. The difference between the values of these two relative exposures represents the roentgen energy absorbed by the artery, and the ratio of these two values is the relative attenuation of the incident roentgen beam. This ratio will be called the 'attenuation factor'. Large amounts of iodinated material in the artery will cause a marked attenuation of the roentgen ray beam. The 'attenuation factor' of the artery studied is compared with the 'attenuation *factor' of various standard tubes filled with known con*

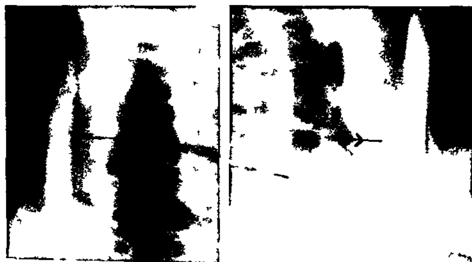


Fig 5 Relative dilution of the contrast agent by various flow rates

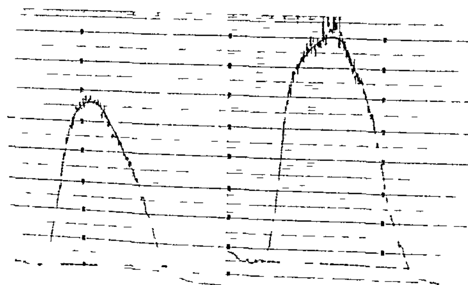


Fig 6 Densitometric tracing of the two vessels in fig 5

centrations of contrast medium (Fig 2) From this comparison the concentration of the contrast medium in the artery is determined Two roentgenograms are thus required one is taken during the slow constant rate injection of the contrast medium in the artery (100 ml/min) and the other is taken with the



Fig 7 Angiogram in late arterial phase showing a tumor stain

set of standard tubes superimposed on the patients without any injection (Figs 1 and 2)

Catheterization and injection technique The cases reported here were all catheterized through a subclavian puncture as reported in a previous publication (AMPLATZ 1963) *After the angiogram is performed a fine teflon* catheter (0 8 mm in diameter) is passed through the catheter used for angiography The tip of this minute teflon tubing is positioned either in the common carotid artery (Fig 1) or in the internal carotid artery depending on where the flow is to be measured No difficulty has been encountered by the author in threading this catheter up to the origin of the internal carotid artery In addition to the fact that this small catheter allows the selective injection of the contrast medium in either the common carotid or the internal carotid, it also sprays the contrast medium into the artery since it has a closed end and a few minute side holes This spray insures turbulent flow and adequate mixture of the blood and the indicator In order to assure a constant rate of injection through the high resistance presented by the narrow tubing a special injector has been built This injector has a powerful synchronous motor driving the plunger of a steel syringe

The densitometer used for these measurements provides a projection screen on which the area of the film is viewed and in the center of this area the exact position of the scanning light beam is observed As mentioned above, the diameter of this scanning light beam is 40 micron The optical density is recorded on a strip chart recorder (Fig 6) *From the tracing obtained the concentration* of the opaque indicator in the artery is determined (The densitometer is available from the National Spectrographic Laboratories, Cleveland Ohio)





Fig 8 *Upper view* Digital presentation of regional flow obtained by Hilal Dual Densitometer from film of fig 7 *Right* Magnified view of tumour area Numbers represent volume of contrast medium expressed in fractions of ml present in a rectangular region measuring 3 mm × 4 mm

Results

The blood flow rate has been determined on 18 patients with this method Only three representative cases will be reported here

The first case is a 55 year old patient with no organic neurologic disease and with normal angiography Multiple flow measurements were made on each common carotid artery

Rt com carot flow in ml/min 547 533 533 Avg 538

Lt com carot flow in ml/min 497 489 497 500 Avg 496

This case is presented to illustrate the repeatability of the results Every figure reported here represents a separate injection and of course a separate film on which the densitometric measurements were made

The second case is a patient with a 60 narrowing of the left internal carotid at the bifurcation (Fig 3)

Rt int carot flow in ml/min 288 291 Avg 290

Lt int carot flow in ml/min 139 138 Avg 139

This 60 narrowing of the internal carotid artery has caused a reduction of the flow to about 48 of the rate of flow of the opposite side

The third case is that of a patient with an occlusion of the left middle cerebral artery (Figs 4 5 and 6) The flow determined in each internal carotid artery is as follows

Rt int carot flow ml min 22? 301 Avg 262

Lt int carot flow ml min 179 20? 147 177 Avg 176

This flow on the left side is reduced by 33 as compared with the flow on the right side

Discussion

From the examples given it is evident that the repeated determination of the flow in the same vessel by this method provides fairly consistent results

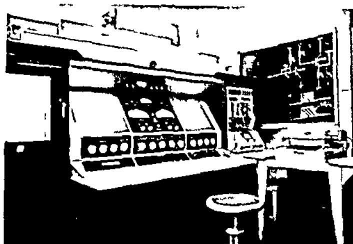


Fig. 9. General view of the Hilal Dual Densitometer.

indicating that the various radiographic procedures can be adequately controlled for the purpose of this work. It is also important to note that the variation between repeated determinations is much smaller than the variation between the normal and the pathologic states.

The results obtained here for the normal carotid flow agree with the measurements made by KRISTIANSEN & KROG (1962) and TINDALL et coll. (1962) using the electromagnetic flow meter. These results are also in fair agreement with those obtained by SHENKIN et coll. (1948) and by NYLIN (1961) using a non diffusable indicator.

Since the flow is determined in individual vessels by this method, the hemodynamic significance of a single stenosis can be assessed. This information could be important in the evaluation of a patient for vascular surgery. On the other hand, when a method that measures total cerebral flow is used the disturbance resulting from a particular localized vascular region is difficult to assess because the compensatory increase in the flow in the other functioning vessels will overshadow this disturbance.

Regional blood flow determination. This procedure is still in the experimental stage and no sufficient data are available for critical appraisal. A brief description, however, is given here. As in the intracarotid injection of isotopes (FAZIO et coll. 1963) the rate of renewal of the cerebral blood pool can be calculated from the measurement of the density of a particular region on all the films of an angiographic series. In the radiographic method, however, in addition to this information, we have the concentration of the indicator in the arterioles supplying the region of interest and the veins draining it. From these data the size of the regional cerebral blood pool studied can be determined and the

actual regional flow can be calculated The apparatus necessary to make these measurements has been designed by the author and built for this purpose (Fig 9) It consists of a dual densitometer capable of scanning two films the first is the regional film before the injection of the contrast agent and the second is a film from the angiographic series Provision is made for the accurate alignment of the two films so that identical regions of the skull are scanned on the films The signals from the photomultipliers are received by a computer which through a process of logarithmetic subtraction of the optical densities of the two films determines the quantity of contrast medium in the area scanned The results are presented in digital form as shown in Fig 8 Each of these numbers represents the volume of the indicator present in a rectangular area measuring 3 × 4 mm The spatial resolution obtained by this method evidently exceeds the capabilities of any isotope technique

Acknowledgements

This research was supported in part by Grant No 5 R01 HE-08785 of the National Institutes of Health and in part by Grants No 5-T 1 NB 5?98-05 and No NB 03364 of the National Institute of Neurological Diseases and Blindness

SUMMARY

A method for the determination of the blood flow in individual carotid arteries is presented The results are consistent when repeated in the same artery and are in agreement with the values obtained by other investigators This method offers the possibility of determining the hemodynamic disturbance resulting from a localized stenosis A technique for the measurement of regional cerebral blood flow is briefly described This method is still in the preliminary stage

ZUSAMMENFASSUNG

Eine Methode zur Bestimmung der Blutzirkulation der Carotiden wird beschrieben Bei wiederholter Bestimmung in derselben Arterie sind die Resultate konstant und stimmen mit den Werten anderer Untersuchungen überein Diese Methode bietet die Möglichkeit für die Bestimmung von hämodynamischen Störungen die von einer lokalisierten Stenose her stammen Die Technik der Messung der regionalen Blutzirkulation wird in groben Zugen beschrieben Die Methode befindet sich noch in einem vorläufigen Stadium

RÉSUMÉ

L auteur présente une méthode de mesure du débit sanguin dans chaque artere carotide Des mesures répétées dans la meme artère donnent des résultats constants et en accord avec les valeurs obtenues par d autres expérimentateurs Cette méthode permet d étudier les

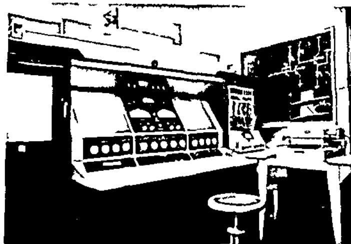


Fig. 9. General view of the Hilal Dual Densitometer

indicating that the various radiographic procedures can be adequately controlled for the purpose of this work. It is also important to note that the variation between repeated determinations is much smaller than the variation between the normal and the pathologic states.

The results obtained here for the normal carotid flow agree with the measurements made by KRISTIANSEN & KROG (1962) and TINDALL et coll. (1962) using the electromagnetic flow meter. These results are also in fair agreement with those obtained by SHENKIN et coll. (1948) and by NYLIN (1961) using a non diffusable indicator.

Since the flow is determined in individual vessels by this method, the hemodynamic significance of a single stenosis can be assessed. This information could be important in the evaluation of a patient for vascular surgery. On the other hand, when a method that measures total cerebral flow is used the disturbance resulting from a particular localized vascular region is difficult to assess because the compensatory increase in the flow in the other functioning vessels will overshadow this disturbance.

Regional blood flow determination. This procedure is still in the experimental stage and no sufficient data are available for critical appraisal. A brief description, however, is given here. As in the intracarotid injection of isotopes (FAZIO et coll. 1963), the rate of renewal of the cerebral blood pool can be calculated from the measurement of the density of a particular region on all the films of an angiographic series. In the radiographic method, however, in addition to this information, we have the concentration of the indicator in the arterioles supplying the region of interest and the veins draining it. From these data the size of the regional cerebral blood pool studied can be determined and the

actual regional flow can be calculated The apparatus necessary to make these measurements has been designed by the author and built for this purpose (Fig 9) It consists of a dual densitometer capable of scanning two films the first is the regional film before the injection of the contrast agent, and the second is a film from the angiographic series Provision is made for the accurate alignment of the two films so that identical regions of the skull are scanned on the films The signals from the photomultipliers are received by a computer which through a process of logarithmetic subtraction of the optical densities of the two films determines the quantity of contrast medium in the area scanned The results are presented in digital form as shown in Fig 8 Each of these numbers represents the volume of the indicator present in a rectangular area measuring 3×4 mm The spatial resolution obtained by this method evidently exceeds the capabilities of any isotope technique

Acknowledgements

This research was supported in part by Grant No 5 R01 HE 08785 of the National Institutes of Health and in part by Grants No 5-T 1 NB 5298 05 and No NB 03364 of the National Institute of Neurological Diseases and Blindness

SUMMARY

A method for the determination of the blood flow in individual carotid arteries is presented The results are consistent when repeated in the same artery and are in agreement with the values obtained by other investigators This method offers the possibility of determining the hemodynamic disturbance resulting from a localized stenosis A technique for the measurement of regional cerebral blood flow is briefly described This method is still in the preliminary stage

ZUSAMMENFASSUNG

Eine Methode zur Bestimmung der Blutzirkulation der Carotiden wird beschrieben Bei wiederholter Bestimmung in derselben Arterie sind die Resultate konstant und stimmen mit den Werten anderer Untersuchungen uberein Diese Methode bietet die Moglichkeit fur die Bestimmung von hamodynamischen Storungen die von einer lokalisierten Stenose herstammen Die Technik der Messung der regionalen Blutzirkulation wird in groben Zugen beschrieben Die Methode befindet sich noch in einem vorlaufigen Stadium

RÉSUMÉ

L auteur présente une méthode de mesure du débit sanguin dans chaque artère carotide Des mesures répétées dans la même artère donnent des résultats constants et en accord avec les valeurs obtenues par d autres expérimentateurs Cette méthode permet d étudier les

perturbations hémodynamiques résultant d une sténose localisée L auteur décrit brièvement une technique de mesure du débit cérébral régional Cette méthode est encore au stade préliminaire

REFERENCES

AMPLATZ K RESCH J and HILAL S A catheter approach for cerebral angiography Radiology 81 (1963) 576

FAZIO C FIESCHI C and AGNOLI A Direct common carotid injection of radioisotopes for the evaluation of cerebral circulatory disturbances A study of 116 cases by bilateral radioisotope rheoencephalography Neurology 13 (1963) 561

HARDESTY W H, ROBERTS B TOOLE J F and ROYSTER H P Studies on carotid artery flow Surgery 49 (1961) 251

KRISTIANSEN K and KROG J Electromagnetic studies on the blood flow through the carotid system in man Neurology 12 (1962) 20

NYLIN G HEDLUND S and REGNSTROM O Studies of the cerebral circulation with labeled erythrocytes in healthy man Circulat Res 9 (1961) 664

SHENKIN H HORMEL M and KETY S Dynamic anatomy of cerebral circulation Arch Neurol Psychiat 60 (1948) 240

STEWART G N Researches on circulation time and on influences which affect it IV Output of the heart J Physiol 22 (1897) 159

TINDALL G T ODOM G L CUPP H B and DILLON M L Studies on carotid flow and pressure J Neurosurg 19 (1962) 917

FROM THE MAYO CLINIC AND MAYO FOUNDATION ROCHESTER MINNESOTA U S A

EVALUATION OF CLOSED CIRCUIT TELEVISION TECHNICS IN NEUROROENTGENOLOGY

by

COLIN B HOLMAN

Closed circuit television technics are being employed in diagnostic roentgenologic practice in ever increasing numbers and in a variety of procedures Basically these include two fundamental and different applications which at times may be combined namely as a medium of rapid, visual communication and as a method of image enhancement for improvement in diagnosis The first category includes transmission of the fluoroscopic image to various monitoring and recording devices as well as transmission of a film image to one or more remote monitors for observation The second category includes any applications relating to the manipulation of the roentgenographic or roentgenoscopic image in order to bring out information that might not be apparent on ordinary inspection The most dramatic and practical application in this regard is the performing of the subtraction technic using various contrast studies Other applications include magnification of the image and changing within limits the density and contrast of various roentgenograms Bas relief effects can be produced for teaching purposes, and relative measuring of certain anatomic structures and locations can be done This presentation will be limited to the second category although it is realized that the chief

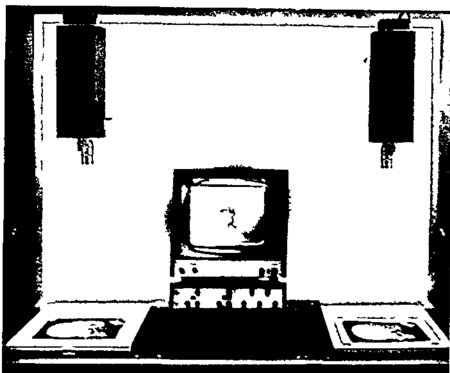


Fig 1 Closed circuit television apparatus arranged for simultaneous projection of two roentgenograms

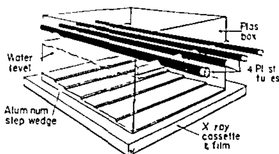


Fig 2 Phantom for studying resolution of density of various *concentrations* of *contrast* medium when projected through aluminum step wedge

applications of closed circuit television to date have been those relating to its use as a medium of communication

Image enhancement or manipulation has been a goal of photographic technics for many years, and most if not all of these procedures have been applied at one time or another to roentgenograms The advent of television brought yet another technic to alter various images and therefore it is reasonable to expect these methods to be adapted to radiology

It is well known that the density and contrast of a television image may be altered within limits and this is at times a rapid practical, and useful way of

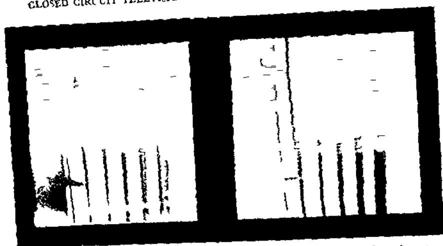


Fig 3 Images of tubes filled with contrast material are not resolved better by subtraction as density of background increases



Fig 4 a) Right retrograde brachial angiography anteroposterior projection No aneurysm visible b) Visible on subtraction Large aneurysm arising at junction of right vertebral artery and basilar artery

improving some roentgenograms The success of this manipulation depends as much upon the lens system the size of the camera diaphragm opening and the illumination of the viewing box as it does on the television system The television image is of a somewhat different quality from that of the film and certainly does lack some sharpness of detail However it is doubtful that there

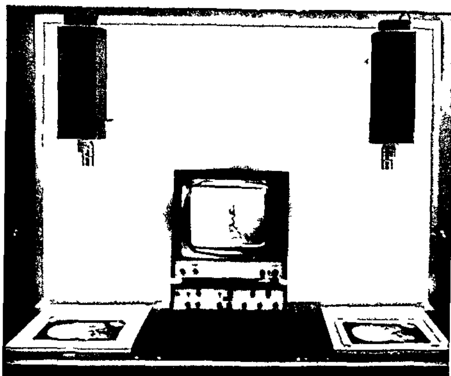


Fig 1 Closed circuit television apparatus arranged for simultaneous projection of two roentgenograms

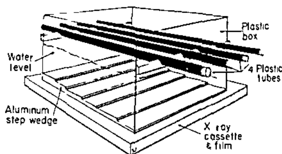


Fig 2 Phantom for studying resolution of density of various concentrations of contrast medium when projected through aluminum step wedge

applications of closed circuit television to date have been those relating to its use as a *medium of communication*

Image enhancement or manipulation has been a goal of photographic technics for many years, and most, if not all, of these procedures have been applied at one time or another to roentgenograms The advent of television brought yet another technic to alter various images and therefore it is reasonable to expect these methods to be adapted to radiology

It is well known that the density and contrast of a television image may be altered within limits and this is at times a rapid, practical, and useful way of



Fig 6 Right retrograde angiography submentovert projection in the same case as in figs 4 and 5 The aneurysm more evident than in the su study

simultaneously (Fig 1) One camera projects the image of the pre film The other camera projects the dipositive image of the contr Synchronized signals from both cameras are applied simultaneously same television monitor This permits cancelling out of the elements c to each roentgenogram leaving for study an image of those elements not c to each in this case the contrast material The resultant subtractio can then be changed by altering density and contrast or it may be m

It is possible to apply this method routinely in all cases of cerebra graphy in order to study more easily the structures filled with contrast and also to identify in some cases collections of contrast material in vessels or aneurysms that are not apparent because of overlying o structures on ordinary inspection of the roentgenogram It has been successfully also to encephalography and gas myelography

In an effort to determine experimentally whether one could expe any structures that were not visible at all on a regular angiogram the experiment was done

Plastic tubes of varying calibers were filled with dilute solutions of material These were placed in a water phantom on the floor of w placed an aluminum step wedge (Fig 2) Films of the phantom v exposed with and without the opaque medium in the tubes and the subtraction studies were made It was evident (Fig 3) that the tubes f



Fig 5 Same case as in fig 4 a) Right retrograde brachial angiography lateral projection Aneurysm obscured by dense bone at base of skull b) Television subtraction Aneurysm projected in anterior portion of foramen magnum

is much advantage in employing a system with more scanning lines than are used with the present commercial television systems Optical magnification at the camera lens is a rapid, convenient and effective procedure and it is possible to achieve a high order of magnification with which to study details of structures that are difficult to observe on inspection of the original film For example, it is possible to resolve between 200 and 300 lines per inch with a lens system and an ordinary closed circuit television system In the case of the appreciation of tiny vessels the limiting factor does not seem to be the resolving power of the television system but the fact that the vessels, being very small, cannot contain enough contrast material to absorb photons of energy to such a degree that a visible difference from the surroundings will arise

Reversal of the roentgen image so that a dipositive picture is obtained is also a simple maneuver with a television system Occasionally this subjectively improves the roentgenographic image This is the manner in which many European medical journals print their roentgenograms

Image reversal is the key to television subtraction and it is in this field that the television system has been of most immediate help The advantages of photographic subtraction in some examinations are well known The principal advantage of the television method is the extreme rapidity with which high quality subtraction studies may be accomplished

Briefly the method consists of employing two closed circuit television cameras

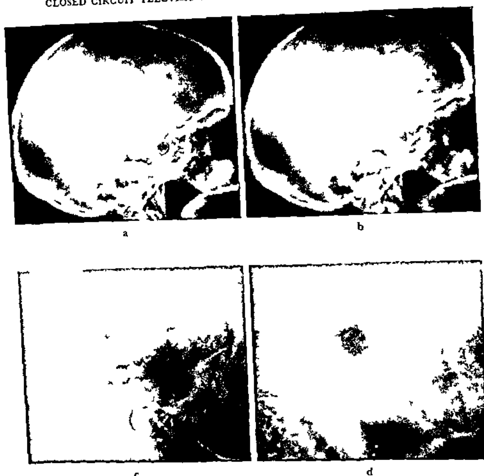
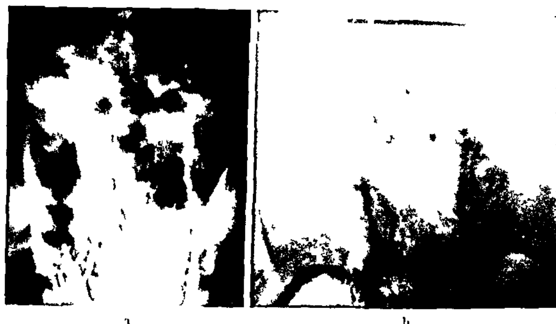


Fig 8) L teral roentgenogram of head sho i g osteoma of tuberculum sellae b) Angiography of th comm n rotid artery m da ter al phase lateral projection c) Television subtraction study f fig 8b howing the vascular port on of the tumor around the osteoma and extending into sella turci d Te e isi n ubtrac on study of fig 8c magn fied on television monitor

Perhaps the most valuable common use of this technic is in the study of vessels that are partly hidden by structures at the base of the skull and the cervical spine such as in angiography of the vertebrobasilar system It is possible to make the examination using any projection because the vessels will not be obscured by overlying bone This applies to the venous sinuses as well as to the arterial supply Similarly poorly contrast filled vascular tumors are seen with great clarity although they might be overlooked on the regular film examination



a b

Fig 7 (a) Vertebral angiogram obtained by injection of contrast material into aortic arch The *vessels are obscured by base of skull and cervical spine (b) Television subtraction The arteries are visible*

contrast material could not be seen any further through the step wedge with subtraction than they could without this process, thus indicating what might be predicted namely that the subtraction study seemed to have its merit in distinguishing contrast filled structures from other details of similar density rather than in revealing a totally new structure on the roentgenogram This is a surprisingly valuable procedure however, because not infrequently lesions are discovered which are missed on ordinary inspection The following examples serve to illustrate

Fig 4a is the anteroposterior angiogram of a patient who previously had been examined twice for subarachnoid bleeding Even a careful study of the film at the region of the foramen magnum does not reveal any particularly important abnormality Fig 4b shows the subtraction study which demonstrated an aneurysm located at the origin of the basilar artery The contrast medium within this aneurysm was present on the original examination but could not be seen because of overlying structures Fig 5a shows a lateral view of the same patient In this instance it is noted that the aneurysm again overlies the posterior fossa and is seen only on the subtraction study (Fig 5b) Fig 6 shows a submentovertical view of a third injection to prove that the aneurysm is actually present, although it obviously is not more evident than in the subtraction study

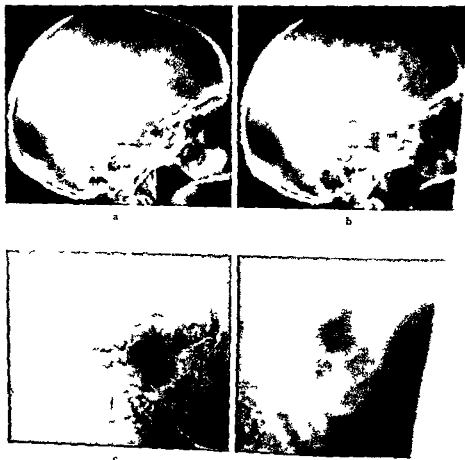


Fig 8 [illegible] Lateral r entgeno ram of head show ng [illegible] of th com non ca ot d artery m darteri l phase [illegible] of fig 8b show ng the vascular po tion of the tum r [illegible] tu [illegible] d Te ev on subtrac ion study of fi 8c [illegible]

Fig 7a shows the vertebral arteries obscured by the overlying cervical spine and base of the skull but in Fig 7b it is easy to see the contrast filled vessels. Fig 8 shows the possibility of enhancing a poorly contrast filled tumor. The lateral film of the head (Fig 8a) shows an osteoma arising from the tuberculum sellae. It was known that meningioma should be present in this region but the extent of the soft tissue portion could not be appreciated. Fig 8b shows the midarterial phase which does not give a clear view of the perfused tumor. The subtracted image of the same picture is shown in Fig 8c. The black, contrast filled vascular portion of the tumor extending well down into the sella turcica is apparent. Fig 8d represents a magnification also immediately done on the television monitor, giving a good view of the tumor extending into the sella turcica.

Two other uses of this apparatus warrant mention. For teaching purposes it is possible to produce bas relief effects by offsetting the images of two identical roentgenograms. This is just an extension of the photographic method known for years and it normally aids in the study of roentgen anatomy.

Another use concerns the production of matching overlay studies which differ in size. Thus, for example, it is possible to match the pineal localization graph to any particular head in order to determine whether the calcification lies within the normal range. One can also superimpose the radioisotope scan film on the roentgenogram and obtain an idea of the localization of the lesion. This, of course, can be done directly, but it is sometimes of help to change the density or contrast, or both, of one or the other image to appreciate the information.

It is thought that closed circuit television systems offer great convenience as a medium of roentgenographic communication, but perhaps just as significantly, within limits, they permit certain manipulations of the roentgenographic image in order to obtain rapidly more information of diagnostic value than it is possible to obtain with direct study of the film, and it is in this field that it is suggested that more investigation should be carried out.

SUMMARY

Closed circuit television technics enhance some radiologic examinations. Subtraction studies are easily performed with two synchronized television cameras linked to a single TV monitor. Angiographic details are more readily appreciated than when viewed on the original angiogram. Ordinary closed circuit television systems can resolve as many as 300 lines per inch so that the limiting factor is not the television system but the contrast in roentgenographic densities between tiny structures and the background.

ZUSAMMENFASSUNG

Geschloss ne Stromkreis Television intensifiert einige radiologischen Untersuchungen Subtraktionsstudien sind mit zwei synchronisierten TV Kameras die an einen einzigen TV Monitor angeschlossen sind leicht durchzufuhren Angiographische Details treten viel deutlicher hervor als am Originalangiogramm Das Auflosungsvermogen einer gewohnlichen geschlossenen Stromkreis TV ist so hoch wie 300 / inch so dass die obere Begrenzung nicht durch das TV System sondern durch den rontgenographischen Kontrast von Struktur und Hintergrund gegeben ist

RÉSUMÉ

Les techniques de télévision en circuit fermé ont fait progresser certains examens radiologiques La soustraction est facilement réalisée au moyen de deux caméras de télévision synchronisées reliées au meme récepteur de TV Des détails angiographiques sont plus facilement appréciés que par l examen des angiographies originales Les systemes courants de télévision en circuit fermé ont un pouvoir de résolution de 300 lignes par pouce de sorte que le facteur limitant n est pas le systeme de télévision mais le contraste des densités radiographiques entre les structures fines et le fond

BIBLIOGRAPHY

HANAFEE W and STOUT P Subtraction technic Radiology 79 (1962) 658

HOLMAN C B Diagnostic applications of closed circuit television in neuroroentgenology Amer J Roentgenol 91 (1964) 1163

— and BULLARD F E The application of closed circuit television in diagnostic roentgenology Proc Mayo Clin 38 (1963) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol Diagnosis 2 (1964) 264

WALLMAN H and WICKBOM I Roentgen television equipment for use in surgery Acta radiol 51 (1959 297

ZIEDSES DES PLANTES B G Subtraktion Eine rontgenographische Methode zur separaten Abbildung bestimmter Teile des Objekts Fortschr Rontgenstr 52 (1935) 69

Fig 7a shows the vertebral arteries obscured by the overlying cervical spine and base of the skull but in Fig 7b it is easy to see the contrast filled vessels. Fig 8 shows the possibility of enhancing a poorly contrast filled tumor. The lateral film of the head (Fig 8a) shows an osteoma arising from the tuberculum sellae. It was known that meningioma should be present in this region but the extent of the soft tissue portion could not be appreciated. Fig 8b shows the midarterial phase which does not give a clear view of the perfused tumor. The subtracted image of the same picture is shown in Fig 8c. The black, contrast filled vascular portion of the tumor extending well down into the sella turcica is apparent. Fig 8d represents a magnification also immediately done on the television monitor, giving a good view of the tumor extending into the sella turcica.

Two other uses of this apparatus warrant mention. For teaching purposes it is possible to produce bas relief effects by offsetting the images of two identical roentgenograms. This is just an extension of the photographic method known for years and it normally aids in the study of roentgen anatomy.

Another use concerns the production of matching overlay studies which differ in size. Thus, for example, it is possible to match the pineal localization graph to any particular head in order to determine whether the calcification lies within the normal range. One can also superimpose the radioisotope scan film on the roentgenogram and obtain an idea of the localization of the lesion. This, of course, can be done directly, but it is sometimes of help to change the density or contrast, or both, of one or the other image to appreciate the information.

It is thought that closed circuit television systems offer great convenience as a medium of roentgenographic communication, but perhaps just as significantly, within limits, they permit certain manipulations of the roentgenographic image in order to obtain rapidly more information of diagnostic value than it is possible to obtain with direct study of the film, and it is in this field that it is suggested that more investigation should be carried out.

SUMMARY

Closed circuit television technics enhance some radiologic examinations. Subtraction studies are easily performed with two synchronized television cameras linked to a single TV monitor. Angiographic details are more readily appreciated than when viewed on the original angiogram. Ordinary closed circuit television systems can resolve as many as 300 lines per inch so that the limiting factor is not the television system but the contrast in roentgenographic densities between tiny structures and the background.

ZUSAMMENFASSUNG

Geschlossene Stromkreis Television intensifiert einige radiologischen Untersuchungen Subtraktionsstudien sind mit zwei synchronisierten TV Kameras, die an einen einzigen TV Monitor angeschlossen sind leicht durchzufuhren Angiographische Details treten viel deutlicher hervor als am Originalangiogramm Das Auflosungsvermogen einer gewohnlichen geschlossenen Stromkreis TV ist so hoch wie 300 / inch so dass die obere Begrenzung nicht durch das TV System sondern durch den rontgenographischen Kontrast von Struktur und Hintergrund gegeben ist

RÉSUME

Les techniques de télévision en circuit fermé ont fait progresser certains examens radiologiques La soustraction est facilement réalisée au moyen de deux caméras de télévision synchronisées reliées au même récepteur de TV Des détails angiographiques sont plus facilement appréciés que par l examen des angiographies originales Les systèmes courants de télévision en circuit fermé ont un pouvoir de résolution de 300 lignes par pouce de sorte que le facteur limitant n est pas le systeme de télévision mais le contraste des densités radiographiques entre les structures fines et le fond

BIBLIOGRAPHY

HANAFEE W and STOUT P Subtraction technic Radiology 79 (1962) 658

HOLMAN C B Diagnostic applications of closed-circuit television in neuroroentgenology Amer J Roentgenol 91 (1964) 1163

— and BULLARD F E The application of closed circuit television in diagnostic roentgenology Proc Mayo Clin 38 (1963) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol Diagnosis 2 (1964) 264

WALLMAN H and WICKBOM I Roentgen television equipment for use in surgery Acta radiol 51 (1959 297

ZIEDSES DES PLANTES B G Subtraktion Eine rontgenographische Methode zur separaten Abbildung bestimmter Teile des Objekts Fortschr Rontgenstr 52 (1935) 69

Fig 7a shows the vertebral arteries obscured by the overlying cervical spine and base of the skull but in Fig 7b it is easy to see the contrast filled vessels. Fig 8 shows the possibility of enhancing a poorly contrast filled tumor. The lateral film of the head (Fig 8a) shows an osteoma arising from the tuberculum sellae. It was known that meningioma should be present in this region but the extent of the soft tissue portion could not be appreciated. Fig 8b shows the midarterial phase which does not give a clear view *of the perfused tumor*. The subtracted image of the same picture is shown in Fig 8c. The black, contrast filled vascular portion of the tumor extending well down into the sella *turcica is apparent. Fig 8d represents a magnification also immediately done* on the television monitor, giving a good view of the tumor extending into the sella turcica.

Two other uses of this apparatus warrant mention. For teaching purposes it is possible to produce bas relief effects by offsetting the images of two identical roentgenograms. This is just an extension of the photographic method known for years and it normally aids in the study of roentgen anatomy.

Another use concerns the production of matching overlay studies which differ in size. Thus, for example, it is possible to match the pineal localization graph to any particular head in order to determine whether the calcification lies within the normal range. One can also superimpose the radioisotope scan film on the roentgenogram and obtain an idea of the localization of the lesion. This, of course, can be done directly, but it is sometimes of help to change the density or contrast, or both, of one or the other image to appreciate the information.

It is thought that closed circuit television systems offer great convenience as a medium of roentgenographic communication, but perhaps just as significantly, *within limits, they permit certain manipulations of the roentgenographic* image in order to obtain rapidly more information of diagnostic value than it is possible to obtain with direct study of the film, and it is in this field that it is *suggested that more investigation should be carried out*.

SUMMARY

Closed circuit television technics enhance some radiologic examinations. Subtraction studies are easily performed with two synchronized television cameras linked to a single TV monitor. Angiographic details are more readily appreciated than when viewed on the original angiogram. Ordinary closed circuit television systems can resolve as many as 300 lines per inch so that the limiting factor is not the television system but the contrast in roentgenographic densities between tiny structures and the background.

ZUSAMMENFASSUNG

Geschloss ne Stromkreis Television intensifiert einige radiologischen Untersuchungen Subtraktionsstudien sind mit zwei synchronisierten TV Kameras die an einen einzigen TV Monitor angeschlossen sind leicht durchzufuhren Angiographische Details treten viel deutlicher hervor als am Originalangiogramm Das Auflosungsvermogen einer gewohnlichen geschlossenen Stromkreis TV ist so hoch wie 300 / inch so dass die obere Begrenzung nicht durch das TV System sondern durch den rontgenographischen Kontrast von Struktur und Hintergrund gegeben ist

RÉSUME

Les techniques de télévision en circuit fermé ont fait progresser certains examens radiologiques La soustraction est facilement réalisée au moyen de deux caméras de télévision synchronisées reliées au meme récepteur de TV Des détails angiographiques sont plus facilement appréciés que par l examen des angiographies originales Les systemes courants de télévision en circuit fermé ont un pouvoir de résolution de 300 lignes par pouce de sorte que le facteur limitant n est pas le système de télévision mais le contraste des densités radiographiques entre les structures fines et le fond

BIBLIOGRAPHY

HANAFEE W and STOUT P Subtraction technic Radiology 79 (1962) 658

HOLMAN C B Diagnostic applications of closed circuit television in neuroroentgenology Amer J Roentgenol 91 (1964) 1163

— and BULLARD F E The application of closed-circuit television in diagnostic roentgenology Proc Mayo Clin 38 (1963) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol Diagnosis 2 (1964) 264

WALLMAN H and WICKBOM I Roentgen television equipment for use in surgery Acta radiol 51 (1959 297

ZIEDSES DES PLANTES B G Subtraktion Eine rontgenographische Methode zur separaten Abbildung bestimmter Teile des Objekts Fortschr Rontgenstr 52 (1935) 69

Fig 7a shows the vertebral arteries obscured by the overlying cervical spine and base of the skull but in Fig 7b it is easy to see the contrast filled vessels Fig 8 shows the possibility of enhancing a poorly contrast filled tumor The lateral film of the head (Fig 8a) shows an osteoma arising from the tuberculum sellae It was known that meningioma should be present in this region but the extent of the soft tissue portion could not be appreciated Fig 8b shows the midarterial phase which does not give a clear view of the perfused tumor The subtracted image of the same picture is shown in Fig 8c The black, contrast filled vascular portion of the tumor extending well down into the sella turcica is apparent Fig 8d represents a magnification also immediately done on the television monitor, giving a good view of the tumor extending into the sella turcica

Two other uses of this apparatus warrant mention For teaching purposes it is possible to produce bas relief effects by offsetting the images of two identical roentgenograms This is just an extension of the photographic method known for years and it normally aids in the study of roentgen anatomy

Another use concerns the production of matching overlay studies which differ in size Thus, for example, it is possible to match the pineal localization graph to any particular head in order to determine whether the calcification lies within the normal range One can also superimpose the radioisotope scan film on the roentgenogram and obtain an idea of the localization of the lesion This, of course, can be done directly, but it is sometimes of help to change the density or contrast, or both, of one or the other image to appreciate the information

It is thought that closed circuit television systems offer great convenience as a medium of roentgenographic communication, but perhaps just as significantly, within limits, they permit certain manipulations of the roentgenographic image in order to obtain rapidly more information of diagnostic value than it is possible to obtain with direct study of the film, and it is in this field that it is suggested that more investigation should be carried out

SUMMARY

Closed circuit television technics enhance some radiologic examinations Subtraction studies are easily performed with two synchronized television cameras linked to a single TV monitor Angiographic details are more readily appreciated than when viewed on the original angiogram Ordinary closed circuit television systems can resolve as many as 300 lines per inch so that the limiting factor is not the television system but the contrast in roentgenographic densities between tiny structures and the background

ZUSAMMENFASSUNG

Geschloss ne Stromkreis-Television intensifiert einige radiologischen Untersuchungen Subtraktionsstudien sind mit zwei synchronisierten TV Kameras, die an einen einzigen TV Monitor angeschlossen sind leicht durchzufuhren Angiographische Details treten viel deutlicher hervor als am Originalangiogramm Das Auflosungsvermogen einer gewohnlichen geschlossenen Stromkreis-TV ist so hoch wie 300 / inch so dass die obere Begrenzung nicht durch das TV System sondern durch den rontgenographischen Kontrast von Struktur und Hintergrund gegeben ist

RÉSUMÉ

Les techniques de télévision en circuit fermé ont fait progresser certains examens radiologiques La soustraction est facilement réalisée au moyen de deux caméras de télévision synchronisées reliées au même récepteur de TV Des détails angiographiques sont plus facilement appréciés que par l examen des angiographies originales Les systèmes courants de télévision en circuit fermé ont un pouvoir de résolution de 300 lignes par pouce de sorte que le facteur limitant n est pas le système de télévision mais le contraste des densités radiographiques entre les structures fines et le fond

BIBLIOGRAPHY

HANAFEE W and STOUT P Subtraction technic Radiology 79 (1962) 658

HOLMAN C. B Diagnostic applications of closed circuit television in neuroroentgenology Amer J Roentgenol 91 (1964) 1163

— and BULLARD F E The application of closed circuit television in diagnostic roentgenology Proc Mayo Clin 38 (1963) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol Diagnosis 2 (1964) 264

WALLMAN H and WICKBOM I Roentgen television equipment for use in surgery Acta radiol 51 (1959 297

ZIEDSES DES PLANTES B G Subtraktion Eine rontgenographische Methode zur separaten Abbildung bestimmter Teile des Objekts Fortschr Rontgenstr 5? (1935) 69

FROM THE DEPARTMENT OF RADIOLOGY OF THE MOUNT SINAI HOSPITAL, NEW YORK,
U S A

PRECENTRAL CEREBELLAR VEIN IN ANGIOGRAPHY

by

YUN PENG HUANG and BERNARD S. WOLF

Study of the veins of the posterior fossa is complicated by numerous variations in the course and communications of these vessels. Many of these veins are small and radiographically difficult to demonstrate. Moreover, classical anatomical descriptions of these veins are not sufficiently detailed for radiologic purposes (1, 2, 3, 6, 7, 9, 10, 11). In the radiologic literature (4, 5), only a few major veins have been noted. The purpose of this paper is to describe a specific vein rather constantly seen during vertebral angiography, which has not been clearly described in either the anatomical or the radiologic literature. Since this vein originates in the precentral cerebellar fissure, that is, the fissure between the central lobule of the cerebellum and the lingula, it may be designated as the precentral cerebellar vein or, in suitable context, simply as the precentral vein. In the injection studies performed by JOHANSON (8), this vein is clearly demonstrated although no specific comment was made about this vessel.

On gross inspection of the intact brain only a small portion of the anterior aspect of the cerebellum behind the mid brain is visible unless the brain stem is forcibly separated from the cerebellum. When this is done a surprisingly deep cleft Figs 1 and 2 is exposed extending downward behind the superior and middle cerebellar peduncles over the roof of the upper part of the fourth ven

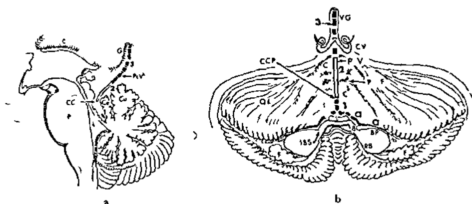


Fig l a) Diagrammatic representation of posterior fossa structures in midline sagittal section First portion (1) of precentral vein (PcV) is located in the fissure between the lingula (L) and the central lobule (Ce) i e in the precentral fissure The colliculo-central point (CCP) is situated between the inferior colliculi (I) in front and the central lobule (Ce) behind Second portion of the vein (2) runs in front of the culmen Third portion (3) runs above the apex of the cerebellum in cisterna ambiens and enters posterior end of great vein of Galen (VG) The first portion of the vein follows a course parallel to the roof of the upper portion of the 4th ventricle Other labeled structures are pineal gland (P) superior colliculi (S) pons (Po) and internal cerebral vein (ICV)
b) Diagrammatic frontal representation of cerebellum with brain stem removed and margins of the anterior cerebellar notch separated This is approximately the view achieved in a 30° ap projection (half axial view) First portion (1) of precentral cerebellar vein (PcV) is formed by the union of symmetrical tributaries (brachial veins) from each side The brachial vein (a and a) begins over brachium pontis (BP) and runs medially over brachium conjunctivum (BC) and lingula (L) to midline The single midline trunk runs upward behind the lingula (The lingula has been reflected and its upper portion removed to expose this portion of the vessel) CCP is the knee or colliculo-central point Second portion (2) of the vein continues upward in front of central lobule (Ce) and the culmen (Cu) Third portion (3) lies above cerebellum within cisterna ambiens and behind great vein of Galen (VG) Other labeled structures Interbrachial sulcus (IBS) inferior cerebellar peduncle or restiform body (RB) wing of central lobule (Ala) preculminate fissure (PcuF) flocculus (F) and quadrangula lobule (QL)

tricle toward the fastigium The central lobule of the cerebellum lies in the mid portion of the posterior wall of the cleft The wings or alae of the central lobule lie in the posterior wall of this cleft in its lateral portion The cleft as a whole seems to have no specific anatomical designation Its central portion however corresponds to the precentral fissure It would therefore seem appropriate to refer to the lateral portions of this cleft as the lateral extensions or wings of the *precentral fissure It should be noted* however, that the quadrangular lobule on each side contributes to the uppermost portion of the posterior wall of this cleft as it extends forward to be applied to the postero lateral aspect of the brain stem The superior paravermian or paramedian sulcus separates the central lobule from its wings and continues upward on each side of the culmen to the highest point or apex of the cerebellum

The configuration of the anterior wall of the precentral fissure and its wings

Fig. 2. a) Lateral view of posterior fossa structures with cerebellum in situ. Portions of superior *vermis and adjacent hemisphere have been removed to expose brachium conjunctivum* (BC) and brachium pontis (BP) as they join the cerebellum. The fine brachial vein (a) originates on brachium pontis (BP) and continues backward (a) over interbrachial sulcus (IBS) and brachium conjunctivum (BC) to lateral margin of lingula at lower end of paravermian sulcus. Small perforating veins (b) from the substance of the cerebellum join the vein in this region. The vein then runs upward and forward in precentral fissure (1) to reach the surface of cerebellum immediately behind inferior colliculi (I). A small lingular tributary (LT) from the lateral aspect of the lingula joins *the vein at this level. Other labeled structures are: Basal vein* (BV), *lemniscal trigone* (*LTr*), fifth nerve (5N), quadrangular lobule (QL), lateral mesencephalic sulcus (LMS) and pontomesencephalic sulcus (LMS). b) Section through upper part of 4th ventricle. Plane of section is oblique to the long axis of the brain stem cutting through lower pons anteriorly and the brachia conjunctiva (BC) posteriorly. The mid portion (PceLM) and the lateral extensions (LceLF) of the precentral fissure are shaded. The two tributaries, brachial veins (unlabeled arrows) which unite to form the precentral cerebellar vein proper are located on each side of the lingula (L). The dotted lines in the *lateral extensions of the precentral fissure represent the brachial veins at levels below the plane of* this section. The dotted line in the central portion of the fissure represents transverse communicating channels. Other labeled structures are: Culmen (CU), central lobule (CL), preculminate fissure (PcuF), paravermian sulcus (PVS), wing of central lobule (ALA), internal velo conjunctival sulcus (IVCS), external velo conjunctival sulcus (EVCS), anterior medullary velum (AMV), interbrachial sulcus (IBS), brachium pontis (BP), quadrangular lobule (QL).

is complicated by the numerous structures in this area. In the mid portion, *these include from above downward, the medial portions of the inferior* colliculi, the frenulum veli, and the lingula overlying the anterior medullary velum. The lateral extensions of the precentral cerebellar fissure extend not only laterally but also anteriorly and include in the anterior wall, the lateral portions of the inferior colliculi, the superior cerebellar peduncles and more laterally the lemniscal trigones and posterior aspects of the middle cerebellar peduncles. Between the superior cerebellar peduncle (brachium conjunctivum) and the middle cerebellar peduncle (brachium pontis) on each side, there is a sulcus designated as the interbrachial or interpeduncular sulcus (not the interpeduncular fossa). The anterior part of the wing rests in this sulcus. The lateral mesencephalic sulcus leads into the interbrachial sulcus from above,



Fig 3 Normal precentral cerebellar vein a) Venous phase of vertebral angiography lateral view The precentral vein (1 2 3) begins (1) in the precentral fissure between the lingula and the central lobule The most anterior point (P) corresponds to the colliculo central point The vein runs upward a short distance in front of the cerebellum (2) and then above the cerebellum (3) in the cisterna ambiens to enter the posterior end of the great vein of Galen b) A p half axial view The two tributaries or brachial veins (1 1) run medially and upward for a short distance before they fuse to form a single trunk (2) which continues upward and backward The terminal portion of the vein (3) is obscured by the great vein of Galen and the straight sinus The single midline trunk and the two diverging tributaries have the appearance of an inverted Y

while the ponto mesencephalic sulcus leads into it from in front It should be emphasized that the structures in the anterior wall of the cleft specifically the inferior colliculi the brachia conjunctiva the lingula and the anterior medullary velum make up the roof of the lower part of the aqueduct and upper part of the fourth ventricle

Because of the important anatomical relationships of the precentral fissure and its lateral extensions a diagnostic landmark to determine the location and configuration of this cleft would be of considerable use Occasionally on encephalography gas may enter this cleft Under ordinary circumstances however no substantial amount of gas is seen below the level of the inferior colliculi The precentral cerebellar vein and its tributaries described below are located in this cleft and appear to be more useful as landmarks for the structures in this region

In a typical case (Fig 3) the precentral cerebellar vein is a single unpaired vessel in the mid line It runs upward in front of the anterior aspect of the superior vermis that is in front of the central lobule and the culmen and

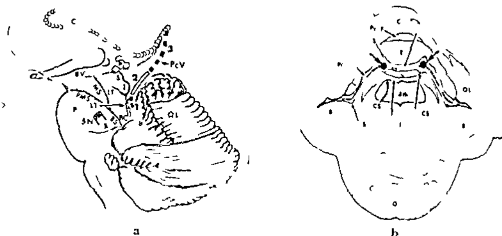


Fig. 2. a) Lateral view of posterior fossa structures with cerebellum in situ. Portions of superior vermis and adjacent hemisphere have been removed to expose brachium conjunctivum (BC) and brachium pontis (BP) as they join the cerebellum. The fine brachial vein (a) originates on brachium pontis (BP) and continues backward (a) over interbrachial sulcus (IBS) and brachium conjunctivum (BC) to lateral margin of lingula at lower end of paravermian sulcus. Small perforating veins (b) from the substance of the cerebellum join the vein in this region. The vein then runs upward and forward in precentral fissure (1) to reach the surface of cerebellum immediately behind inferior colliculi (I). A small lingular tributary (LT) from the lateral aspect of the lingula joins the vein at this level. Other labeled structures are: Basal vein (BV), lemniscal trigone (LTr), fifth nerve (5N), quadrangular lobule (QL), lateral mesencephalic sulcus (LMS) and pontomesencephalic sulcus (PMS). b) Section through upper part of 4th ventricle. Plane of section is oblique to the long axis of the brain stem cutting through lower pons anteriorly and the brachia conjunctiva (BC) posteriorly. The mid portion (PceF M) and the lateral extensions (PceF L) of the precentral fissure are shaded. The two tributaries, brachial veins (unlabeled arrows) which unite to form the precentral cerebellar vein proper are located on each side of the lingula (L). The dotted lines in the lateral extensions of the precentral fissure represent the brachial veins at levels below the plane of this section. The dotted line in the central portion of the fissure represents transverse communicating channels. Other labeled structures are: Culmen (CU), central lobule (CL), preculminate fissure (PcuF), paravermian sulcus (PVS), wing of central lobule (ALA), internal velo-conjunctival sulcus (IVCS), external velo-conjunctival sulcus (EVCS), anterior medullary velum (AMV), interbrachial sulcus (IBS), brachium pontis (BP), quadrangular lobule (QL).

is complicated by the numerous structures in this area. In the mid portion, these include from above downward, the medial portions of the inferior colliculi, the frenulum veli, and the lingula overlying the anterior medullary velum. The lateral extensions of the precentral cerebellar fissure extend not only laterally but also anteriorly and include in the anterior wall, the lateral portions of the inferior colliculi, the superior cerebellar peduncles and more laterally the lemniscal trigones and posterior aspects of the middle cerebellar peduncles. Between the superior cerebellar peduncle (brachium conjunctivum) and the middle cerebellar peduncle (brachium pontis) on each side, there is a sulcus designated as the interbrachial or interpeduncular sulcus (not the interpeduncular fossa). The anterior part of the wing rests in this sulcus. The lateral mesencephalic sulcus leads into the interbrachial sulcus from above,

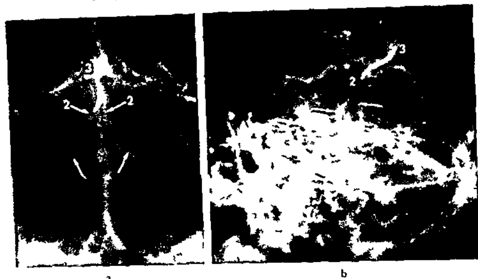


Fig 5 Normal variation of the precentral cerebellar vein a) Half axial a p veiw shows two independent vessels (2) which run upward and medially and unite to form a single trunk (3) in the upper part of the cisterna ambiens These vessels begin as tortuous small veins (unlabeled arrows) located behind the midbrain on each side b) Lateral view The usual first portion of the precentral cerebellar vein is absent Instead the vein appears to begin in a club-shaped density (anterior arrow) which represents the tortuous tributaries on the posterior aspect of the midbrain The second portion of the vein (2) appears to be single but as indicated in the a p projection is probably a double channel A large superior vermian vein around the apex of the cerebellum runs forward to join the precentral cerebellar vein As a result the third portion of this vessel (3) is unusually large There is a sizeble anterior tributary of the superior vermian vein (posterior arrow) The lower portion of this vessel arises in the preculminate fissure while its upper part is directly applied to the anterior aspect of the culmen of the cerebellum

precentral vein runs forward as well as upward to reach the surface of the cerebellum At the point where the vein leaves the precentral fissure, the vessel lies immediately behind and below the inferior colliculi and makes a distinct turn backward as it continues upward in front of the superior vermis (culmen) The vein follows this upward course until it joins the posterior end of the great vein of Galen at its junction with the straight sinus

The normal appearance on vertebral angiography of the precentral cerebellar vein and its tributaries corresponds to the anatomical relationships described above In the lateral projection this vein appears to begin as a single trunk in the depths of the precentral cerebellar fissure This portion of of the vessel may be designated as the first portion In some cases it appears to be composed in the depths of the fissure of superimposed tributaries of the two sides rather than a single trunk However the point of union of these tributaries in the lateral projection is rarely evident The course of the first

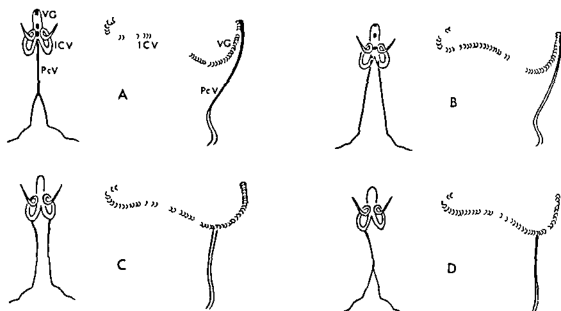


Fig. 4. Normal variations in the course of the precentral cerebellar vein and its tributaries. A) The two tributaries which arise over the brachium pontis and run medially extend upward for a variable distance as independent vessels before they fuse to form a single mid line trunk. Precentral vein (PcV), internal cerebral vein (ICV), vein of Galen (VG). B) The point of union occurs unusually high or a short distance before the main trunk joins the posterior end of the great vein of Galen. As a result, the usual single precentral cerebellar vein is represented by two rather long vessels for most of its extent. C) The precentral cerebellar veins are shown as completely independent vessels running a short distance from the midline and entering the internal cerebral vein of each side rather than the great vein of Galen. D) Occasionally, the tributaries of the precentral cerebellar vein join to form a single trunk which runs upward to one side of the midline to enter the internal cerebral vein of that side.

drains into the posterior end of the great vein of Galen. It is formed by the union of symmetrical tributaries from each side which originate in the lateral extensions of the precentral cerebellar fissure and run medially within this fissure to join one another in the midline. Each tributary may be said to originate from small veins on the superior aspect of the brachium pontis and to run as a 'brachial' vein medially and backward across the interbrachial sulcus and the brachium conjunctivum to reach the posterior aspect of the lingula. As it runs over these structures, it assumes a configuration corresponding to their external contour. It is of interest that anatomical dissections show minute perforating twigs from the white matter of the cerebellum joining each brachial vein at the lateral margin of the base of the lingula or the lower end of the paravermian sulcus. Other fine veins from the lingula, colliculi and superior surface of the cerebellum may also join this venous pathway.

The union of the two symmetrical tributaries or brachial veins which form the single unpaired trunk, i.e. the precentral cerebellar vein proper, usually occurs in the depths of the precentral fissure. As a result, the first portion of the



Fig 7 Venous phase of vertebral angiography half axial a p view The two brachial veins (a) are united by a transverse communicating branch (c) The combination of these vessels corresponds to the trapezoid outline of the roof of the upper portion of the fourth ventricle The brachial vein are separated from the ventricle by the brachia conjunctiva and the communicating vessel by the lingula and the superior medullary velum The superior continuation toward the midline of both brachial veins can be faintly seen (1 1)

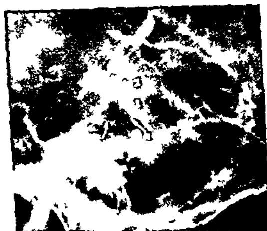


Fig 8 Variation in the drainage of the precentral cerebellar vein lateral view The first (1) and second (2) portions of the precentral vein are small channels but normally situated Drainage however is not only upward but also downward and forward via the brachial vein (a and a) This vessel empties into the superior petrosal sinus via the petrosal vein

what upward to reach the mid line These tributaries and the central unpaired stem give the appearance of an inverted Y with a long stem Unfortunately in this projection the terminal portion of the vein is usually obscured by the overlying great vein of Galen and straight sinus

The description given above of the typical precentral cerebellar vein and its main tributaries should be considered as a prototype subject to variations Fig 4 The point of union of the two tributaries may not occur exactly in the midline but rather a short distance to one side More commonly the two tributaries fail to unite in the precentral cerebellar fissure itself but continue as individual trunks upward for a variable distance before joining (Figs 5 and 6) In such cases the two tributaries often communicate with each other

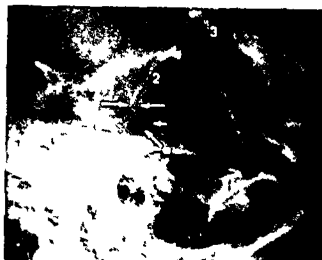


Fig. 6. Venous phase of vertebral angiography, lateral view. *The precentral vein (long transverse arrows) is double throughout much of its extent. A portion of the brachial vein (a) running over the brachium conjunctivum can be identified. This channel joins the main tributary in the precentral fissure almost at a right angle (short transverse arrow). This junction may be used to identify the lowermost point of the paravermian sulcus.*

portion of this vein as it runs forward and upward is exactly parallel to the roof of the upper part of the fourth ventricle but separated from it by the thickness of the roof, or 2 to 4 mm. As the vein leaves the precentral fissure and turns backward between the central lobule of the cerebellum and the inferior colliculi, a characteristic obtuse angle or knee in the course of the vessel is created. The most anterior point of this angle may be referred to as the 'colliculo central point', or for brevity, the 'C C point'. Similarly, the angle may be designated as the 'colliculo central angle' or simply as the 'C C angle'. For purposes of description, the next portion of the precentral cerebellar vein which continues upward and backward in front of the superior vermis may be designated as the second portion. It usually shows a slight curvature convex anteriorly. This portion of the vein does not run directly on the surface of the cerebellum but a short distance in front of the cerebellum. The distance between this vein and the surface of the cerebellum is well seen when the *anterior tributary of the superior vermian vein is also filled* with contrast medium. The portion of the precentral vein above the level of the cerebellum within the central portion of the cisterna ambiens, that is, the third or terminal portion of the vein, continues without interruption the upward and backward course of the second portion. This third part often shows slight convexity posteriorly *although it may be straight or show a slight anterior convexity.* The second and third portions of the vessel may therefore have a somewhat sinuous appearance or show a smooth anterior convexity. In the fronto occipital projection with the central ray tilted 25 to 30 degrees toward the feet (half axial a p view), the symmetrical tributaries or brachial veins which unite to form the *unpaired precentral cerebellar vein run medially* and some



Fig 10 Venous phase of vertebral angiography lateral view The three portion of the precentral cerebellar vein (1 2 3) as well as the colliculo-central point (P) are well seen A somewhat tortuous cortical vein (unlabeled arrow) from the superior aspect of the cerebellar hemisphere runs medially upward and forward to join the precentral vein



Fig 11 Normal variation of the precentral cerebellar vein The first portion of the precentral cerebellar vein (1) and the colliculo-central point (P) have a normal configuration and location However the vessel extends vertically upward and enters the internal cerebral vein (unlabeled arrow) rather than the posterior end of the great vein of Galen

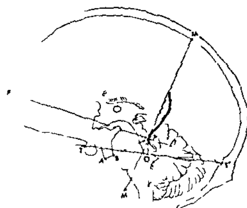
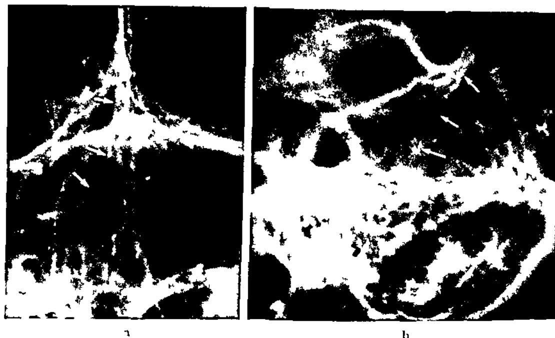


Fig 12 Normal measurements of the colliculo-central point A variety of measurements from the colliculo-central point (P) to other anatomical landmarks are indicated PA is the minimum distance from P to the clivus B = the anterior aspect of the pons F = the inner table of the frontal bone M = the anterior margin of the foramen magnum or the lower end of the clivus M' = the inner table or the parietal bone T = the tuberculum sellae T t = the torcula TT' Twining's line Q is the foot of a perpendicular line dropped from P to TT'

region of the flocculus to join the petrosal vein (Fig 8) More commonly, however the mid line precentral cerebellar vein is replaced by a somewhat similar vessel located in the lateral extension or wing of the precentral cerebellar fissure (Fig 9) This vessel runs upward and backward to one side of the mid line but may also join the posterior end of the great vein of Galen In the antero posterior projection such a paracentral or lateral precentral cerebellar



a b

Fig 9 Paracentral or lateral precentral cerebellar vein a) Half axial a p view There is a sizeable rather long vein (arrows) which begins inferiorly at some distance from the midline and runs upward and medially in the lateral and central portions of the precentral cerebellar fissure to the paravermian sulcus This vessel approaches but does not reach the midline until the upper portion of the cisterna ambiens b) Lateral view showing the same vein (arrows) which resembles the usual midline precentral cerebellar vein However the first portion of the precentral vein and the knee or colliculo central angle are absent and this vessel is considerably straighter As indicated in the a p projection the portion of this vein in front of the cerebellum does not run in the midline but is more laterally located

at various levels but particularly in the bottom of the precentral fissure by transverse connections designated as communicating veins (Fig 7) These anastomotic twigs are of special interest since they lie immediately behind the roof of the upper part of the fourth ventricle and, in combination with the brachial veins, serve to delineate the trapezoid configuration of the roof of the upper part of the fourth ventricle There are numerous variations in the confluence of the precentral, superior vermian, internal occipital and medial temporal cortical, choroid, basal and other veins with the internal cerebral veins and the great vein of Galen A not uncommon variation is the union of the precentral cerebellar vein with the superior vermian vein to form a short common stem *within the cisterna ambiens These variations in terminal* drainage are of little diagnostic importance

The precentral cerebellar vein is not evident in all patients In some cases it may be quite small In such instances, venous drainage may occur in an anterior direction via brachial veins which run forward and laterally to the

angulation in its course In the lateral projection confusion may also arise when a cerebellar cortical vein on the superior aspect of the hemisphere runs upward and forward and may simulate the first portion of the pre central vein (Fig 10) Such a vessel however is located more posteriorly and does not show the typical colliculo central angle It should also be men tioned that the superior vermian vein usually has an anterior tributary which may be confused with the precentral vein This tributary typically arises in the fissure between the culmen and the central lobule (preculminate fissure), runs directly on the anterior aspect of the culmen and therefore has a some what scalloped appearance However the precentral cerebellar vein may occasionally be more posteriorly located than usually seen and replace the anterior tributary of the superior vermian vein The precentral vein may also run unusually far forward and extend almost directly upward to join the internal cerebral vein to one side of the mid line (Fig 11)

As described above the first segment of the precentral cerebellar vein runs parallel and posterior to the roof of the upper part of the fourth ventricle and the lower portion of the aqueduct Deformities and displacements of this segment and of the C C point can therefore be interpreted in a fashion similar to the well known changes in the aqueduct and fourth ventricle seen on ence phalograms Measurements of the C C point in relation to osseous anatomical landmarks may therefore be as useful as measurements of the aqueduct and fourth ventricle in encephalograms (Fig 12 Table) The minimal distance from this point to the posterior aspect of the clivus averaged 3 9 cm with a range of 3 6 to 4 3 cm as measured in 40 presumably normal adult angiograms The fact that the perpendicular line dropped from this point to Twining s tuberculum torcular line approximately bisects the latter line is al o a useful guide In most cases with displacement or deformity of the precentral cerebellar vein visual inspection is sufficient to recognize the presence of an abnormality (Figs 13 and 14)

SUMMARY

The course and appearance of the precentral cerebellar vein is described in detail The first portion of this vein within the precentral cerebellar fissure lies parallel to and behind the roof of the upper part of the fourth ventricle The vein can be divided into three portions with the junction between the first and second portions forming a characteris ic angle referred to as the colliculo-central angle the most anterior part of his angle may be designated the colli culo-central point The location of this point and the configuration of this angle is of diagnostic importance in recognizing deformities and displacements



Fig 13 Chordoma Vertebral angiography venous phase lateral projection A large calcified mass is present in the region of the destroyed *dorsum sellae* The first and second portions of the precentral vein (1 2) are displaced markedly backward This is evident by the increased distance between this vessel and anterior structures such as the sella turcica and the clivus as well as the decreased distance to posterior structures such as the straight sinus The colliculo central angle (P) is flattened The third portion of the vein (3) and adjacent great vein of Galen are vertical in position



Fig 14 Tentorial notch meningioma arising from the junction of falx and tentorium A large mass supplied by meningeal vessels (M M) is present in the region of the incisura All three portions of the precentral cerebellar vein (1 2 3) are displaced forward and follow a single continuous curved course The aqueduct and posterior portion of the third ventricle must also be displaced markedly forward in an arcuate fashion Large choroidal veins (unlabeled arrow) within the velum interpositum are also evident

vein is easily distinguished from the more common mid line precentral cerebellar vein In the lateral view, however, these vessels may be confused In this projection, the paracentral cerebellar vein is located more anteriorly than the usual precentral cerebellar vein and does not show any knee or

Table

Measurements of the colliculo central point — For measurement points see Fig 12

	Lower limit	Upper limit	Mean		Lower limit	Upper limit	Mean
AP	3 6 cm	4 3 cm	3 9 cm	$\frac{TQ}{TT'}$	44	55	49
BP	2 9 cm	3 6 cm	3 [illegible] cm				
				$\frac{TP}{TT}$	60	72	66 %
MP	4 0 cm	5 8 cm	4 8 cm				
QI	0 6 cm	1 6 cm	1 1 cm	$\frac{MP}{MM'}$	30	42	36 %

angulation in its course In the lateral projection confusion may also arise when a cerebellar cortical vein on the superior aspect of the hemisphere runs upward and forward and may simulate the first portion of the pre central vein (Fig 10) Such a vessel however, is located more posteriorly and does not show the typical colliculo central angle It should also be men tioned that the superior vermian vein usually has an anterior tributary which may be confused with the precentral vein This tributary typically arises in the fissure between the culmen and the central lobule (preculminate fissure) runs directly on the anterior aspect of the culmen and therefore has a some what scalloped appearance However, the precentral cerebellar vein may occasionally be more posteriorly located than usually seen and replace the anterior tributary of the superior vermian vein The precentral vein may also run unusually far forward and extend almost directly upward to join the internal cerebral vein to one side of the mid line (Fig 11)

As described above the first segment of the precentral cerebellar vein runs parallel and posterior to the roof of the upper part of the fourth ventricle and the lower portion of the aqueduct Deformities and displacements of this segment and of the C C point can therefore be interpreted in a fashion similar to the well known changes in the aqueduct and fourth ventricle seen on ence phalograms Measurements of the C C point in relation to osseous anatomical landmarks may therefore be as useful as measurements of the aqueduct and fourth ventricle in encephalograms (Fig 12 Table) The minimal distance from this point to the posterior aspect of the clivus averaged 3 9 cm with a range of 3 6 to 4 3 cm as measured in 40 presumably normal adult angiograms The fact that the perpendicular line dropped from this point to Twining s tuberculum torcular line approximately bisects the latter line is al o a useful guide In most cases with displacement or deformity of the precentral cerebellar vein visual inspection is sufficient to recognize the presence of an abnormality (Figs 13 and 14)

SUMMARY

Th course and appearance of the precentral cerebellar vein is described in detail The first portion of this vein within the precentral cerebellar fissure lies parallel to and behind the oof of th upper part of th fourth ventricle The vein can be divided into three portions with th junction between the first and second portions forming a characteris ic angle referred to as the colliculo-central angle the most anterior part of this angle may be designated the colli culo-central point The location of this point and the config ıration of this angle is of diagnostic importance in recognizing deformities and displacements

ZUSAMMENFASSUNG

Es wird der Verlauf und das Aussehen der präzentralen cerebellaren Vene im Detail beschrieben Der erste Abschnitt dieser Vene in der präzentralen cerebellaren Fissur ist hinter dem Dach des oberen Teiles des vierten Ventrikels und parallel zu ihm gelegen Die Vene kann in drei Abschnitte eingeteilt werden wobei der Übergang vom ersten zum zweiten Abschnitt einen charakteristischen Winkel bildet welcher als colliculo zentraler Winkel beschrieben wird Der vorderst gelegene Teil dieses Winkels mag als 'colliculo zentraler Punkt bezeichnet werden Die Lage dieses Punktes und die Form des Winkels ist von diagnostischer Bedeutung in der Erkennung von Deformierungen und Dislokationen

RÉSUMÉ

Les auteurs décrivent en détail le trajet et l aspect de la veine cérébelleuse précentrale La première partie de cette veine dans le sillon cérébelleux précentral est située parallèlement au toit de la partie supérieure du quatrième ventricule en arrière de ce toit On peut diviser la veine en trois parties l union de la première et de la seconde formant un angle caractéristique appelé 'angle colliculo central la partie la plus antérieure de cet angle peut être appelée le point colliculo central La localisation de ce point et la configuration de cet angle ont une importance diagnostique pour reconnaître les déformations et les déplacements

REFERENCES

1 BROWNING W The veins of the brain and its envelopes Their anatomy and bearing on the intracranial circulation I B O Connor Jr Brooklyn New York 1884

2 BAILEY P Intracranial tumors 2nd ed Charles C Thomas Publishers Springfield Illinois 1948

3 DURET H Recherches anatomiques sur la circulation de l encephale Arch Physiol norm et path 6 (1874) 316

4 GREITZ T and LINDGREN E Cerebral vascular anatomy In Angiography Vol 1 Ed by H Abrams Little Brown & Co Boston 1961

5 HAUGE T Catheter vertebral angiography Acta radiol Suppl 109 1954

6 HEDON C F Etude anatomique sur la circulation veineuse de l encephale Thèse Bordeaux 1888

7 HOFMAN M Zur vergleichenden Anatomie der Gehirn u Ruckenmarksvenen der Vertebraten Ztsch f Morphol u Anthropol 3 (1901) 239

8 JOHANSON C Central veins and deep dural sinuses of brain Anatomical and angiographic study Acta radiol Suppl 107 1954

9 METTLER F Neuroanatomy The C V Mosby Co St Louis 1948

10 PADGET D H Development of cranial venous system in man from viewpoint of comparative anatomy Contrib Embryol 36 (1957) 79

11 POIRIER P CHARPY A and NICHOLAS A Traité d anatomie humaine Vol III Masson & Cie Paris 1921

FROM THE NEUROSURGICAL CLINIC UNIVERSITY OF ZURICH SWITZERLAND

PERCUTANEOUS VERTEBRAL ANGIOGRAPHY

by

H KRAYENBUHL and M G YASARGIL

Within a ten year period 1 035 vertebral angiographies were done on 900 *patients using the technique* of percutaneous (ventro cervical) puncture of the vertebral artery This procedure was carried out under *general anesthesia* exclusively in order to decrease the danger of arterial spasm as well as to render the puncture painless

Good filling of the vertebral artery and its intracranial branches was obtained in 80 % *of the cases The contrast filling* of the vessels was insufficient in 10 % and in another 10 % the puncture was *unsuccessful* Complications were rare and minor they consisted in either local or radicular pain both disappearing within a short time One patient was lost owing to accidental intrathecal injection of the contrast substance This fatal complication could have been avoided if proper attention had been *given* to the position of the needle

The indication for the performance of angiography was given in the following groups of neurological disorders Vascular diseases 365 cases (40 5 %) tumors 212 cases (23 5 %) cerebello-bulbo pontine syndrome (tumors not included) 275 cases and miscellaneous *diseases* (migraine trauma mono paresis epilepsy and others) 66 cases (together 36 0 %)

ZUSAMMENFASSUNG

Es wird der Verlauf und das Aussehen der präzentralen cerebellaren Vene im Detail beschrieben. Der erste Abschnitt dieser Vene in der präzentralen cerebellaren Fissur ist hinter dem Dach des oberen Teiles des vierten Ventrikels und parallel zu ihm gelegen. Die Vene kann in drei Abschnitte eingeteilt werden, wobei der Übergang vom ersten zum zweiten Abschnitt einen charakteristischen Winkel bildet, welcher als colliculo-zentraler Winkel beschrieben wird. Der vorderst gelegene Teil dieses Winkels mag als colliculo-zentraler Punkt bezeichnet werden. Die Lage dieses Punktes und die Form des Winkels ist von diagnostischer Bedeutung in der Erkennung von Deformierungen und Dislokationen.

RÉSUMÉ

Les auteurs décrivent en détail le trajet et l'aspect de la veine cérébelleuse précentrale. La première partie de cette veine, dans le sillon cérébelleux précentral, est située parallèlement au toit de la partie supérieure du quatrième ventricule, en arrière de ce toit. On peut diviser la veine en trois parties, l'union de la première et de la seconde formant un angle caractéristique appelé angle colliculo-central; la partie la plus antérieure de cet angle peut être appelée le point colliculo-central. La localisation de ce point et la configuration de cet angle ont une importance diagnostique pour reconnaître les déformations et les déplacements.

REFERENCES

1. Browning, W.: The veins of the brain and its envelopes. Their anatomy and bearing on the intracranial circulation. F. B. O'Connor Jr., Brooklyn, New York, 1884.
2. Bailey, P.: Intracranial tumors. 2nd ed. Charles C Thomas Publishers, Springfield, Illinois, 1948.
3. Duret, H.: Recherches anatomiques sur la circulation de l'encéphale. Arch. Physiol. norm. et path. 6 (1874), 316.
4. Greitz, T. and Lindgren, E.: Cerebral vascular anatomy. In: Angiography, Vol. 1. Ed. by H. Abrams. Little Brown & Co., Boston, 1961.
5. *Hauge, T.: Catheter vertebral angiography. Acta radiol. Suppl. 109, 1954.*
6. Hédon, C. E.: Étude anatomique sur la circulation veineuse de l'encéphale. Thèse, Bordeaux, 1888.
7. Hofmann, M.: Zur vergleichenden Anatomie der Gehirn- u. Rückenmarksvenen der Vertebraten. Ztsch. f. Morphol. u. Anthropol. 3 (1901), 239.
8. Johanson, C.: Central veins and deep dural sinuses of brain. Anatomical and angiographic study. Acta radiol. Suppl. 107, 1954.
9. Mettler, F.: Neuroanatomy. The C. V. Mosby Co., St. Louis, 1948.
10. Padget, D. H.: Development of cranial venous system in man from viewpoint of comparative anatomy. Contrib. Embryol. 36 (1957), 79.
11. Poirier, P., Charpy, A. and Nicholas, A.: Traité d'anatomie humaine. Vol. III. Masson & Cie, Paris, 1921.

Table 2

Tumors (212 cases)

	No. of cases		Per cent
Supratentorial			
Frontal, temporal, parietal		14	6.6
Occipital	27	52	24.5
Mesodiencephal	25	52	24.5
Infratentorial			
Cerebello-pontine angle	56		
Cerebellum	77		
Pons	8	141	66.1
Cervical spine	3	5	2.4
Malformations	2	5	2.4

size, vascularization and exact localization if details with respect to roentgenologic anatomy are sufficiently known (GALLOWAY & GREITZ 1960, WOLF et coll. 1962, YASARGIL 1962, GREITZ & SJOGREN 1963, ECONOMOS & PROSALENTIS 1963).

Vertebral angiography is of increasing diagnostic importance in cases with an unclear or atypical symptomatology with either isolated or combined signs of bulbar, pontine or cerebellar lesions. Occasionally it is difficult to decide whether or not one is dealing with a vascular, inflammatory, degenerative, posttraumatic or even neoplastic condition. It is of great value to exclude by means of a negative vertebral angiography the presence of a tumor. Thus an explorative occipital craniotomy may be avoided. In none of the 323 cases with negative angiograms was a tumor diagnosed even after a follow up of many years.

Vertebral angiography is a valuable aid in the diagnostic evaluation of certain atypical cases by permitting differentiation between a tumor and a vasculopathy such as an aneurysm or an angioma.

SUMMARY

Within a 10 year period (1953—1963) 1 035 percutaneous vertebral angiographies were performed in 900 cases. 23 % were tumors (1/3 supra-, 2/3 infratentorial), 40 % were cases with vascular disease and 37 % cases with signs of an unknown pontine bulbar-cerebellar symptomatology. This investigation demonstrated that vertebral angiography is of great clinical value for the diagnosis of suspected intracranial tumor and of vascular diseases.

Table 1

Vascular diseases (365 cases)

	No. of cases		Per cent
Arteriosclerosis occlusion		80	21.9
Aneurysms			
Internal carotid artery and its branches	35		
Posterior communicating artery	23		22.1
Vertebro basilar artery	23	81	
Arteriovenous angiomas			
Cerebral hemispheres	27		
Mesodiencephalon	14		
Infratentorial	12		
Nuchal	5	58	16.0
Subarachnoid hemorrhage		157	43.0
Miscellaneous (fistula, persisting arteries, hematoma)		19	5.2

Pre- and postoperative vertebral angiography is performed in cases of subarachnoid hemorrhage and in cases of vascular occlusions to study the site of the lesion and the collateral circulation (Table 1).

Other angiographic methods such as puncture or catheterization of subclavian, axillary, brachial or femoral arteries are used to study extracranial morphological changes of the cerebral arteries. Extracranial portions are clearly demonstrated by these techniques.

Percutaneous vertebral angiography is particularly suited for the detection of tumors of paratentorial localization. Tentorium, mesodiencephalon, retrosellar and occipito medial regions (LOFGREN 1958), (Table 2). While carotid angiography gives very unsatisfactory results in these cases, vertebral angiography may even allow the drawing of conclusions concerning the type of tumor present.

Vertebral angiography is not very conclusive in the presence of an infratentorial space occupying lesion. Once the tumor has reached a certain size, the clinical symptomatology becomes very clear. An exploration being performed bilaterally in any case, further angiographic localization becomes unnecessary. A small tumor, on the other hand, would cause an insignificant displacement of the vessels. However, the fact must be recalled that a number of tumors often exhibit readily detectable pathological vessels (meningiomas, neurinomas, angiomas, metastases, plexus papillomas, glomus tumors). Angiography allows the diagnosis of these lesions concerning their number,

Table 2

Tumors (212 cases)

	No of cases		Per cent
Supratentorial		14	6 6
Frontal temporal parietal	27	52	24 5
Occipital	25	52	24 5
Mesodiencephal			
Infratentorial			
Cerebello pontine angle	56		
Cerebellum	77		
Pons	8	141	66 1
Cervical spine	3	5	2 4
Malformations	2	5	2 4

size vascularization and exact localization if details with respect to roentgenologic anatomy are sufficiently known (GALLOWAY & GREITZ 1960 WOLF et coll 1962 YASARGIL 1962 GREITZ & SJOGREN 1963 ECONOMOS & PROSALENTIS 1963)

Vertebral angiography is of increasing diagnostic importance in cases with an unclear or atypical symptomatology with either isolated or combined signs of bulbar pontine or cerebellar lesions Occasionally it is difficult to decide whether or not one is dealing with a vascular inflammatory, degenerative posttraumatic or even neoplastic condition It is of great value to exclude by means of a negative vertebral angiography the presence of a tumor Thus an explorative occipital craniotomy may be avoided In none of the 323 cases with negative angiograms was a tumor diagnosed even after a follow up of many years

Vertebral angiography is a valuable aid in the diagnostic evaluation of certain atypical cases by permitting differentiation between a *tumor and* a vasculopathy such as an aneurysm or an angioma

SUMMARY

Within a 10 year period (19[illegible]3—19[illegible]3) 1 03[illegible] percutaneous vertebral angiographies were performed in 900 cases 23 were tumors (1/3 supra 2/3 infratentorial) 40 % were cases with vascular disease and 37 cases with signs of an unknown pontine bulbar cerebellar symptomatology This investigation demonstrated that vertebral angiography is of great clinical value for the diagnosis of suspected *intracranial* tumor and of vascular diseases

Table 1

Vascular diseases (365 cases)

	No. of cases		Per cent
Arteriosclerosis occlusion		80	21.9
Aneurysms			
Internal carotid artery and its branches	35		
Posterior communicating artery	23		22.1
Vertebro basilar artery	23	81	
Arteriovenous angiomas			
Cerebral hemispheres	27		
Mesodiencephalon	11		
Infratentorial	12		
Nuchal	[illegible]	58	16.0
Subarachnoid hemorrhage		157	43.0
Miscellaneous (fistula, persisting arteries, hematoma)		19	5.2

Pre- and postoperative vertebral angiography is performed in cases of subarachnoid hemorrhage and in cases of vascular occlusions to study the site of the lesion and the collateral circulation (Table 1).

Other angiographic methods such as puncture or catheterization of subclavian, axillary, brachial or femoral arteries are used to study extracranial morphological changes of the cerebral arteries. Extracranial portions are clearly demonstrated by these techniques.

Percutaneous vertebral angiography is particularly suited for the detection of tumors of paratentorial localization. Tentorium, mesodiencephalon, retrosellar and occipito medial regions (LOFGREN 1958), (Table 2). While carotid angiography gives very unsatisfactory results in these cases, vertebral angiography may even allow the drawing of conclusions concerning the type of tumor present.

Vertebral angiography is not very conclusive in the presence of an infratentorial space occupying lesion. Once the tumor has reached a certain size, the clinical symptomatology becomes very clear. An exploration being performed bilaterally in any case, further angiographic localization becomes unnecessary. A small tumor, on the other hand, would cause an insignificant displacement of the vessels. However, the fact must be recalled that a number of tumors often exhibit readily detectable pathological vessels (meningiomas, neurinomas, angiomas, metastases, plexus papillomas, glomus tumors). Angiography allows the diagnosis of these lesions concerning their number,

AUS DER NEUROCHIRURGISCHEN UNIVERSITÄTSKLINIK KÖLN UND DEM MAX PLANCK INSTITUT FÜR HIRNFORSCHUNG ABTEILUNG TUMORFORSCHUNG (DIREKTOR PROFESSOR W TÖNNIS) KÖLN DEUTSCHLAND

NEURORADIOLOGISCHE BESONDERHEITEN IM FRÜHSTADIUM DER GROSSHIRN TUMOREN UND BEI REZIDIVEN

von

W Krenkel

Von der Kontrastmittel Untersuchungen verlangen *wir zunächst* den Nachweis eines raumfordernden Prozesses überhaupt und zwar in einem möglichst frühen Stadium sodann für die *Therapie* eine genaue Aussage über die Lokalisation und Ausdehnung und schließlich wird auch ein Beitrag zur Artdiagnose erwartet

Bei den Großhirn Tumoren *wenden wir zuerst* die Serien Angiographie an da sie lokalisatorisch und vielfach artdiagnostisch von entscheidendem Wert ist Im Hinblick auf die Frühdiagnose sind jedoch die Grenzen der Aussagemöglichkeit zu berücksichtigen Dies gilt besonders für die häufig nicht durch pathologische Gefäße dargestellten langsam wachsenden Gliome

Der Bericht stützt die neuroradiologischen Befunde bei 465 histologisch verifizierten Großhirn Geschwulsten *ohne* Stauungspapille und 100 Rezidiv Tumoren Die Diagnose des Tumors basierte in 60 % auf dem angiographischen Befund in 6 % war allein eine Encephalographie angefertigt worden Bei

ZUSAMMENFASSUNG

Innerhalb der letzten 10 Jahre (1953—63) sind an 900 Patienten 1 035 perkutane vertebrale Angiographien durchgefuhrt worden, 23 % waren Tumoren (1/3 supra 2/3 infratentoriell) 10 % vasculare Erkrankungen 37 % mit Anzeichen einer unbekannten pontin bulbaren cerebellaren Symptomatologie Die Untersuchung zeigte dass die vertebrale Angiographie von grosser klinischer Bedeutung für die Diagnosestellung intrakranieller Tumoren und vaskularer Erkrankungen ist

RÉSUMÉ

Au cours d une période de 10 ans (1953—1963) les auteurs ont fait 1 035 angiographies vertébrales percutanées sur 900 sujets 23 % avaient des tumeurs (1/3 supra 2/3 infratentorielles) 40 % *une affection vasculaire et 37 % présentaient une symptomatologie ponto-*bulbo cérébelleuse de cause inconnue Ce travail montre que l angiographie vertébrale a un grand intérêt clinique pour le diagnostic de tumeur intracranienne et d affection vasculaire

REFERENCES

ECONOMOS D et PROSALENTIS A L artère cérébelleuse supérieure dans les tumeurs de la fosse postérieure Acta radiol 1 (1963) 207

HAUGE T The catheter vertebral angiography Acta radiol Suppl 109 (1954)

GALLOWAY J R and GREITZ T The medial and lateral choroid arteries Acta radiol 53 (1960) 353

GREITZ T and SJOGREN S E The posterior inferior cerebellar artery Acta radiol 1 (1963) 284

KRAYENBÜHL H und YASARGIL M G Die vaskularen Erkrankungen im Gebiet der Arteria vertebralis und Arteria basilaris G Thieme Stuttgart 1957

LOFGREN F O Vertebral angiography in the diagnosis of tumors in the pineal region Acta radiol 50 (1958) 108

NAMIN P L artériographie vertébrale G Doin Paris 1955

OLSSON O Vertebral angiography in the diagnosis of acoustic nerve tumors Acta radiol 39 (1953) 265

RADNER S Vertebral angiography by catheterization Acta radiol Suppl 87 (1951)

SJOGREN S E Percutaneous vertebral angiography Acta radiol 40 (1953) 113

WOLF B S NEWMAN C M and KHILNANI M T The posterior inferior cerebellar artery on vertebral angiography Amer J Roentgenol 87 (1962) 322

YASARGIL M G Die Vertebralisangiographie Ihre Bedeutung fur die Diagnose der Tumoren Acta neurochir Suppl 9 (1962)

AUS DER NEUROCHIRURGISCHEN UNIVERSITÄTSKLINIK KÖLN UND DEM MAX PLANCK INSTITUT FÜR HIRNFORSCHUNG, ABTEILUNG TUMORFORSCHUNG (DIREKTOR: PROFESSOR W. TÖNNIS), KÖLN, DEUTSCHLAND

NEURORADIOLOGISCHE BESONDERHEITEN IM FRÜHSTADIUM DER GROSSHIRN-TUMOREN UND BEI REZIDIVEN

von

W. KRENKEL

Von den Kontrastmittel-Untersuchungen verlangen wir zunächst den Nachweis eines raumfordernden Prozesses überhaupt und zwar in einem möglichst frühen Stadium, sodann für die Therapie eine genaue Aussage über die Lokalisation und Ausdehnung, und schließlich wird auch ein Beitrag zur Artdiagnose erwartet.

Bei den Großhirn-Tumoren wenden wir zuerst die Serien-Angiographie an, da sie lokalisatorisch und vielfach artdiagnostisch von entscheidendem Wert ist. Im Hinblick auf die Frühdiagnose sind jedoch die Grenzen der Aussagemöglichkeit zu berücksichtigen. Dies gilt besonders für die häufig nicht durch pathologische Gefäße dargestellten, langsam wachsenden Gliome.

Der Bericht stützt die neuroradiologischen Befunde bei 465 histologisch verifizierten Großhirn-Geschwulsten ohne Stauungspapille und 100 Rezidiv-Tumoren. Die Diagnose des Tumors basierte in 60 % auf dem angiographischen Befund, in 6 % war allein eine Encephalographie angefertigt worden. Bei

33 % erforderte die Angiographie zur genauen Lokalisation eine Ergänzung durch eine Enzephalographie.

Tabelle 1

Diagnose von 465 Großhirntumoren ohne Stauungspapille

Rontgen Nativbild allein	1 %
Carotis Angiographie	60 %
Encephalographie	6 %
Carotis Angiographie und Encephalographie	33 %

Bei einer fruheren Untersuchung, die alle Großhirn Geschwulste unabhängig vom Grad der intrakraniellen Drucksteigerung einbezogen hatte, ergab sich nur in 17,5 % die Notwendigkeit einer kombinierten Kontrastmitteluntersuchung. Das heißt, im Fruhstadium des Geschwulstwachstums darf man sich

Tabelle 2

Angiographische Befunde bei Grosshirn Tumoren ohne Stauungspapille

	Meningiome	Astrocyt	Oligod	Sonstige Gliome	Glioblast	And mal Tu	—
	110	*99*	*96*	*43*	*89*	*28*	*465*
Angio	89	77	77	28	83	23	377
Normal	*3*	*3*	*5*	*3*	*2*	2	18
Fragl Bfd	4	5	*12*	*2*	*2*	—	25
A pericall Verl	2	6	9	1	7	1	26
Arter Gefäß V	*20*	*40*	*31*	15	*30*	7	143
Venen Ausfall	4	8	3	2	8	2	27
Pathol Gefäße	*55*	15	16	5	*33*	10	134
Nicht bewert	1	—	1	—	1	1	4
EG	47	63	58	20	19	8	215
VC	5	13	13	7	*8*	*2*	48
Normal	—	*1*	*1*	*1*	*3*	*1*	7
Balken Septum Schragstand	1	*3*	*6*	1	1	—	12
Seiten Verlag	4	*13*	—	1	*2*	—	20
		2			3		5
Positiv Bfd	36	40	39	15	11	7	148
	5	10	13	6	4	*2*	40
Tu Seite ∅ Fllg	2	*2*	3	2	1	—	*10*
		1					*2*
∅ Fllg	4	4	9	—	1	—	18
					1		1

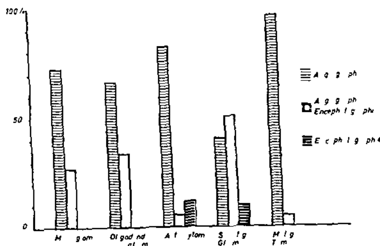


Abb 1 Anteil der einzelnen Kontrastmittel Verfahren bei der Diagnose der cerebralen Re d v Tumoren (100 Tumoren)

bei einem klinisch begrundeten Tumorverdacht nicht mit einer negativ ausgefallenen Kontrastmittel Methode begnugen

Betrachten wir die bei den verschiedenen Tumorarten erzielten Ergebnisse (Tab 2) Es fällt der große Anteil normaler oder fraglicher angiographischer Befunde bei den Oligodendrogliomen (in 22 %) aber auch Ependymomen und Spongioblastomen (in 18 %) auf Die Zahl normaler Encephalogramme ist absolut und relativ geringer Die bei den Astrozytomen recht oft beobachtete isolierte Seitenverlagerung des Ventrikel Systems ist auf die sich diffus ausbreitenden Tumoren zu beziehen Bei den Glioblastomen mit normalen Ventrikelbildern handelte es sich um ein Fruhstadium der Tumor Entwicklung

Tabelle 3

Angiographische Befunde bei frontalen und parietalen Gliomen je Malignitatsgrad

	Angiographie				Encephalographie		
	Normal	Fragl Befund	Allein A pericall Verl	Positiver Befund	Normal	Fragl Befund	Positiver Befund
Lang wachsende Gliome	5	11	3	16	3	5	20
Maligne Gliome = Astr III/Oligo II	—	4	1	21	—	—	18

33 % erforderte die Angiographie zur genauen Lokalisation eine Ergänzung durch eine Enzephalographie.

Tabelle 1

Diagnose von 465 Großhirntumoren ohne Stauungspapille

Röntgen Nativbild allein	1 %
Carotis Angiographie	60 %
Encephalographie	6 %
Carotis Angiographie und Encephalographie	33 %

Bei einer früheren Untersuchung, die alle Großhirn-Geschwülste unabhängig vom Grad der intrakraniellen Drucksteigerung einbezogen hatte, ergab sich nur in 17,5 % die Notwendigkeit einer kombinierten Kontrastmitteluntersuchung. Das heißt, im Frühstadium des Geschwulstwachstums darf man sich

Tabelle 2

Angiographische Befunde bei Grosshirn-Tumoren ohne Stauungspapille

	Meningiome	Astrocyt.	Oligod.	Sonstige Gliome	Glioblast.	And. mal. Tu.	–
	110	99	96	43	89	28	465
Angio	89	77	77	28	83	23	377
Normal	3	3	5	3	2	2	18
Fragl. Bfd.	4	5	12	2	2	—	25
A. pericall. Verl.	2	6	9	1	7	1	26
Arter. Gefäß-V.	20	40	31	15	30	7	143
Venen-Ausfall	4	8	3	2	8	2	27
Pathol. Gefäße	55	15	16	5	33	10	134
Nicht bewert.	1	—	1	–	1	1	4
EG	17	63	58	20	19	8	215
VG	5	13	13	7	8	2	48
Normal	—	1	1	1	3	1	7
Balken-Septum-Schrägstand	1	3	6	1	1	—	12
Seiten-Verlag.	4	13	—	1	2	—	20
		2			3		5
Positiv Bfd.	36	40	39	15	11	7	148
	5	10	13	6	4	2	10
Tu. Seite Ø Füllg.	2	2	3	2	1	—	10
		1					2
Ø Füllg.	4	4	9	–	1	—	18
					1		1

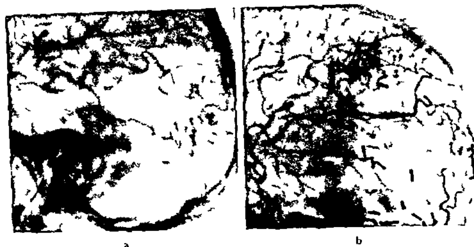


Abb 3 Occipitales Glioblastom a) Carotis Angiographie praoperativ Tumorgefäße occipital b) Carotis-Angiographie 1 5 Jahre postoperativ Neue Tumorgefäße parietal (Rezidiv)

was das Neoplasma im Angiogramm sowohl durch die Parallelverschiebung der A pericallosa als auch durch eine Darstellung pathologischer Gefäße zu erkennen

Bei Berucksichtigung der Tumorlokalisation hat die Angiographie vor allem bei den parasagittalen den in den Stammganglien gelegenen und den parieto occipitalen Prozessen die meisten Versager Der Unterschied zwischen dem angiographischen und encephalographischen Befund kann sehr erheblich sein Bei parasagittalen Geschwulsten sind Rontgenaufnahmen im Sitzen zur fruh zeitigen Erfassung der Gliome unerlaßlich

Neben der unterschiedlichen Aussagemoglichkeit der beiden Kontrastver fahren je Tumorart und Lokalisation kommt auch dem Ausmaß der Umge bungsreaktion große Bedeutung zu Unterscheidet man bei den Oligodendro gliomen und Astrozytomen zwischen den langsam und rasch wachsenden so ergibt sich eindeutig daß bei der ersten Gruppe die Zahl der unsicheren Be funde großer ist Andererseits versagte bei den (rasch wachsenden) Gliomen *II* Grades das Encephalogramm in keinem Fall (Tab 3) Die langsam wach senden Gliome die klinisch fast ausnahmslos unter dem Bild eines Anfalls leidens in Erscheinung treten stellen die schwer diagnostizierbare Tumorgruppe dar Dazu kommt daß auch die Isotopen Untersuchung in diesen Fallen in 40 % negative Ergebnisse liefert Ebensowenig ist von der Echoencephalo graphie in diesem Stadium zu erwarten

Unter unseren 100 Rezidiv Tumoren uber deren Kontrastmittel Befunde

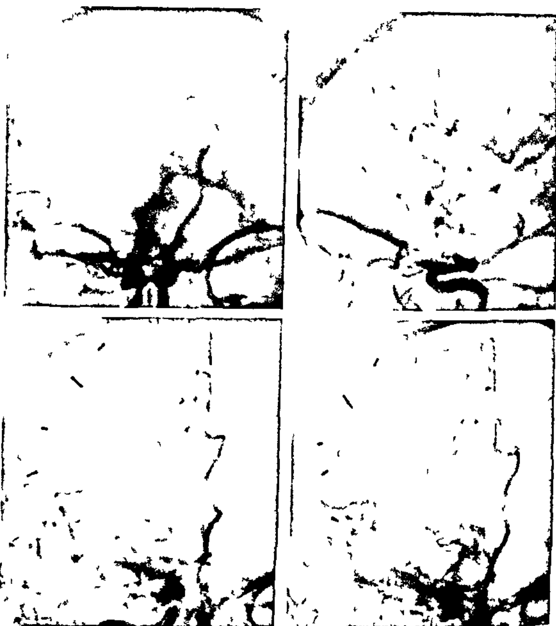


Abb. 2. Präzentrales Glioblastom. *Oben links:* Carotis-Angiographie präoperativ (a. p.). Bogenförmige Verlagerung der A. pericallosa. *Oben rechts:* Seitlich — Pathologische Gefässe präzentral. *Unten links:* Carotis-Angiographie (4 Monate postoperativ). Nur noch geringe Verlagerung der A. pericallosa. *Unten rechts:* Carotis-Angiographie (10 Monate postoperativ). Erneute Zunahme der Massenverschiebung (Rezidiv).

In dem Fall einer 49jährigen Pat. mit einem Glioblastom ergab sich zunächst weder im Angiogramm noch im Encephalogramm ein eindeutiger Hinweis auf einen raumfordernden Prozeß. Zwei Wochen später konnte lediglich ein Schrägstand der *Balkenzisterne* registriert werden. Nach weiteren 6 Wochen





a b

Abb 3 Occipitales Glioblastom a) Carotis-Angiographie präoperativ Tumorgefäße occipital b) Carotis-Angiographie 1 5 Jahre postoperativ Neue Tumorgefäße parietal Rezidiv)

was das Neoplasma im Angiogramm sowohl durch die Parallelverschiebung der A pericallosa als auch durch eine Darstellung pathologischer Gefäße zu erkennen

Bei Berücksichtigung der Tumorlokalisation hat die Angiographie vor allem bei den parasagittalen den in den Stammganglien gelegenen und den parieto-occipitalen Prozessen die meisten Versager Der Unterschied zwischen dem angiographischen und encephalographischen Befund kann sehr erheblich sein. Bei parasagittalen Geschwulsten sind Röntgenaufnahmen im Sitzen zur frühzeitigen Erfassung der Gliome unerläßlich

Neben der unterschiedlichen Aussagemöglichkeit der beiden Kontrastverfahren je Tumorart und Lokalisation kommt auch dem Ausmaß der Umgebungsreaktion große Bedeutung zu Unterscheidet man bei den Oligodendrogliomen und Astrozytomen zwischen den langsam und rasch wachsenden, so ergibt sich eindeutig daß bei der ersten Gruppe die Zahl der Fehlbefunde größer ist Andererseits versagte bei den (rasch wachsenden) Gliomen II Grades das Encephalogramm in keinem Fall (Tab 3 Die rasch wachsenden Gliome die klinisch fast ausnahmslos unter dem Bild eines Hirnleidens in Erscheinung treten stellen die schwer diagnostizierbare Gruppe dar Dazu kommt daß auch die Isotopen Untersuchung in diesen Fällen in 40 % negative Ergebnisse liefert Ebensowenig ist von der Echoencephalographie in diesem Stadium zu erwarten

Unter unseren 100 Rezidiv Tumoren über deren Kontrastmittel Befunde

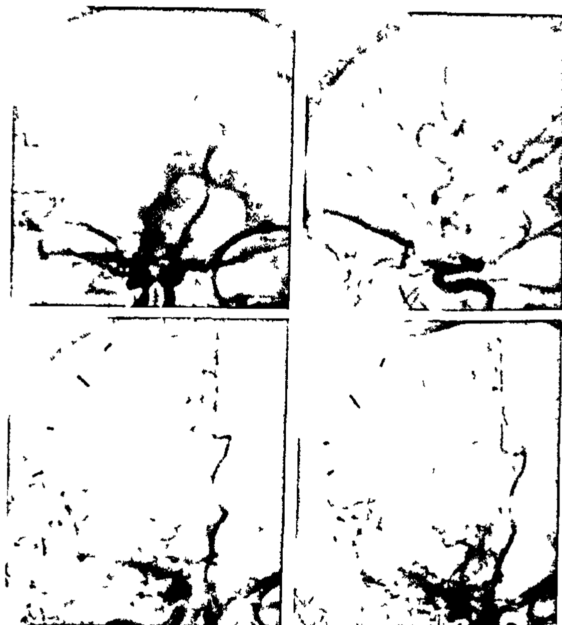
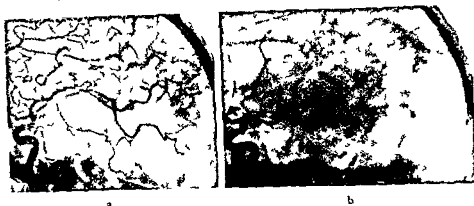


Abb. 2. Präzentrales Glioblastom. *Oben links:* Carotis-Angiographie präoperativ (a. p.). Bogenförmige Verlagerung der A. pericallosa. *Oben rechts:* Seitlich — Pathologische Gefässe präzentral. *Unten links:* Carotis-Angiographie (4 Monate postoperativ). Nur noch geringe Verlagerung der A. pericallosa. *Unten rechts:* Carotis-Angiographie (10 Monate postoperativ). Erneute Zunahme der Massenverschiebung (Rezidiv).

In dem Fall einer 49jährigen Pat. mit einem Glioblastom ergab sich zunächst weder im Angiogramm noch im Encephalogramm ein eindeutiger Hinweis auf einen raumfordernden Prozeß. Zwei Wochen später konnte lediglich ein Schrägstand der Balkenzisterne registriert werden. Nach weiteren 6 Wochen



a b

Abb 4 Temp Oligode drogl om a) Carot s Ang ographie praoperativ Anhebung der A cerebri med gef ßf eier Raum b) Carotis-Angiograph e 2 /1? J postoperativ Tumorgefaße parieto temporal (Rez d v)

rechts) an der neben der Pericallosa die wieder zur Gegenseite verlagert ist auch die Media teilnimmt Diese ist in ihrem Anfangsteil bogig nach unten verlagert Das Rezidiv lag im vorderen Frontalmark ohne daß es zu der sonst typischen bogenformigen Verlagerung der A pericallosa kam Betrachten wir nun den Primartumor so fallt gegenuber dem Rezidiv folgendes auf 1 Primar bestand der fur einen frontalen Tumor typische Pericallosa verlauf 2 das Rezidiv fand sich an anderer Stelle es war von der Grenzzone der Resektion weitergewachsen und 3 nur praoperativ waren Tumorgefaße im Angiogramm nachweisbar Die frontalen Gliom Rezidive lassen fast stets den typischen Pericallosa Verlauf im antero posterioren Strahlengang vermissen Als Erklarung bieten sich die durch die Erstoperation gesetzen Veranderungen wie Hirngewebe Resektion und gliose Narbenbildung an

Der Ortswechsel des Rezidivs ist sehr haufig zu beobachten da sich dieses von der Grenzflache der primaren Resektion aus weiterentwickelt Auch das folgende Angiogramm von einem occipitalen Glioblastom (Abb 3 a und b) zeigt eine Wanderung des Tumors Außerdem kommt es in diesem Fall 15 Monate nach der Entfernung des ersten Tumors sekundar zur Ausbildung neuer pathologischer Gefäße

In beiden zuletzt demonstrierten Fallen war zusatzlich eine lokale Behandlung mit Kobalt 60 erfolgt Man konnte geneigt sein das Verschwinden der Tumorgefaße als eine Folge der Bestrahlung aufzufassen Jedoch zeigte eine Zusammenstellung aller postoperativ bestrahlten Falle sei es mit Rontgenstrahlen mit dem Betatron oder Kobalt daß ein statistisch beweisbarer Einfluß auf die Tumorgefaße gegenuber den nicht bestrahlten nicht vorlag Im

Tabelle 4

Einfluß der Röntgenbestrahlung oder ^{60}Co Behandlung auf die im Angiogramm nachweisbaren Tumorgefäße bei Oligodendrogliomen, Astrozytomen, Ependymomen

	Gesamt Zahl der Gliome	Primär Tu Gefäße + / Rezidiv Tu Gefäße ∅	Primär Tu Gefäße ∅ / Rezidiv Tu Gefäße +	Primär = Rezidiv
Keine Röntgen oder ^{60}Co Behandlung	31	2	5	24
Postoperative Röntgen oder ^{60}Co Behandlung	27	1	13	13
	58	3	18	37

hier berichtet werden soll, finden sich je 20 % Meningiome und maligne Tumoren, d. h. Glioblastome und Sarkome. Die restlichen 60 % werden durch die Gruppe der langsam wachsenden Gliome gestellt.

Die Bestätigung des Rezidivs allein durch die Angiographie gelang am häufigsten bei den Glioblastomen und Sarkomen (Abb. 1). Dagegen war bei der Gruppe der langsam wachsenden Gliome in rund 30 % eine ergänzende Untersuchung durch eine Encephalographie erforderlich. Der Anteil ist bei den Ependymomen und Spongioblastomen ebenso wie bei der Diagnostik des Primärtumors am größten. Auffallend ist jedoch der Unterschied zwischen den Oligodendrogliomen und Astrozytomen. Diese Differenz erklärt sich aus der Tatsache, daß bei den Astrozytomen die Massenverschiebung in der Mehrzahl der Fälle auch beim Kontrollangiogramm zu finden ist, während bei den Oligodendrogliomen die Verlagerung der A. pericallosa sehr oft beim Rezidiv fehlt oder sogar zur operierten Seite hin erfolgt.

Auf den Wechsel der Massenverschiebung haben bereits LINDGREN u. Mitarbeiter bei den Untersuchungen über die Rezidiv-Diagnostik mit Tantalum-Puder aufmerksam gemacht. In den ersten Wochen und Monaten bildet sich die Massenverschiebung zurück, und die A. pericallosa wird infolge der resektionsbedingten Hirnatrophie auf die Operationsseite verlagert.

Bildet sich das Rezidiv im gleichen Hirnlappen, so kann nach anfänglicher Normalisierung im Gefäßverlauf eine erneute Verlagerung auftreten. Im folgenden Fall eines frontoprazentralen Glioblastoms (Abb. 2, oben links u. rechts) ist der Verlauf der A. pericallosa und der A. cerebri media 4 Monate postoperativ annähernd wieder normal (Abb. unten links). Nach weiteren 6 Monaten ist wieder eine Massenverschiebung zu erkennen (Abb. 2, unten

LITERATUR

BREIT A und PFEIFFER I Mehrfache Angiographien wahrend der Rontgenbestrahlung von Hirngeschwulsten Acta radiol 46 (1956) 469

FRANCESCONI G MARZANO E e PAGLICCI A Rilievi angiografici nei processi espansivi endocranici dopo intervento operatorio e trattamento radiante Gazz int Med Chir 64 (1959) 3250

FRIEDMANN G KRENKEL W und TONNIS W Angiographie oder Pneumencephalographie? Fortschr Rontgenstr 96 (1962) 181

GLONING K Tumorrezidive im Angiogramm Acta neurochir Suppl III (1955) 250

KRENKEL W und KROHM G Grenzen der Kontrastmitteldiagnostik im Fruhstadium der Großhirntumoren 45 Tagg Dtsch Rontgengesellschaft Fortschr Rontgenstr 1965 Teil A p 320

LINDGREN M LOFGREN F O and LUNDBERG N Tantalum powder as an indicator of the brain tumour region for postoperative radiotherapy and the diagnosis of recurrence Acta radiol 48 (1957) 17

Gegenteil ergab sich sogar, daß die Rate der kontrastmittelgefüllten Rezidive unter den postoperativ bestrahlten Gliomen größer war als bei den nicht bestrahlten Fällen (Tab. 4).

Bei den folgenden Pat. (Abb. 4a) wurde 1951 ein temporales Oligodendrogliom entfernt und eine Röntgen-Nachbestrahlung mit einer Herddosis 3 000 R durchgeführt. 2 1/2 Jahre später zeigte sich angiographisch (Abb. 4b) ein Rezidiv, das sich nunmehr durch zahlreiche arterio-venöse Fisteln, ähnlich einem Glioblastom, markierte.

Der Anteil der pathologischen Gefäßdarstellungen steigt bei den primär langsam wachsenden Gliomen von 15 % auf 40 % beim Rezidiv-Tumor an. Der Nachweis einer vorzeitigen Venenfüllung aus dem Tumorgebiet kann als sicherer Hinweis auf eine maligne Degeneration des Neoplasma gelten. Außerdem sind Verlagerungen der inneren Venen zu beachten, die ein Rezidiv andeuten können, während eindeutige Verlagerungen der Hauptarterien noch nicht vorliegen.

ZUSAMMENFASSUNG

Im Frühstadium der Großhirn-Geschwülste bewährt sich die Angiographie sowohl in lokalisatorischer als auch artdiagnostischer Hinsicht. Die langsam wachsenden Gliome erfordern häufiger als in einem späteren Stadium des Tumorwachstums eine ergänzende Encephalographie. Bei den Rezidiven sind die infolge der postoperativen Atrophie und Narbenbildung auftretenden Gefäßverlagerungen von den Veränderungen, die durch ein Rezidiv hervorgerufen sind, abzugrenzen. Verlagerungen der A. pericallosa zur Gegenseite bleiben beim Rezidiv oft aus. Der Anteil pathologischer Gefäßdarstellungen steigt bei den *Gliom*rezidiven erheblich an.

SUMMARY

Angiography is of proven merit in the localisation and establishment of the type of early cerebral tumours. Supplementary encephalography is more often required in the early stages of slow growing gliomatas but infrequently in advanced cases. Recurrence necessitates vascular changes due to postoperative atrophy to be distinguished from those due to neoplastic scarring. Displacement of the arteria pericallosa is often absent in the case of recurrent neoplasms. The number of abnormal vessels is much increased in recurrent gliomas.

RÉSUMÉ

Au stade précoce des tumeurs du cerveau l'angiographie a fait ses preuves aussi bien pour la localisation que pour le diagnostic de nature. Les gliomes à croissance lente nécessitent plus souvent une encéphalographie complémentaire à leur stade de début qu'à un stade ultérieur. Dans les récidives il faut distinguer les déplacements de vaisseaux qui sont dus à l'atrophie et à la cicatrice de ceux qui sont causés par une récidive. Les déplacements de l'artère péricalleuse vers le côté opposé sont fréquents dans les récidives. La proportion d'aspects vasculaires pathologiques augmente considérablement en cas de récidive de gliome.

LITERATUR

Brett A und Pfeiffer I Mehrfache Angiographien wahrend der Rontgenbestrahlung von Hirngeschwulsten Acta radiol 46 (1956) 469

Francesconi G Marzano E e Paglicci A Rilievi angiografici nei processi espansivi endocranici dopo intervento operatorio e trattamento radiante Gazz int Med Chir 64 (1959) 3250

Friedmann G Krenkel W und Tonnis W Angiographie oder Pneumencephalographie? Fortschr Rontgenstr 96 (1962) 181

Gloning K Tumorrezidive im Angiogramm Acta neurochir Suppl III (1955) 250

Krenkel W und Krohm G Grenzen der Kontrastmitteldiagnostik im Fruhstadium der Großhirntumoren 45 Tagg Dtsch Rontgengesellschaft Fortschr Rontgenstr 1965 Teil A p 320

Lindgren M Lofgren F O and Lundberg N Tantalum powder as an indicator of the brain tumour region for postoperative radiotherapy and the diagnosis of recurrence Acta radiol 48 (1957) 17

FROM THE NEUROLOGICAL SERVICE OF THE 2ND (CORNELL) MEDICAL DIVISION OF BELLEVUE HOSPITAL, THE DEPARTMENT OF NEUROLOGY IN MEDICINE AND THE DEPARTMENT OF MEDICINE OF THE CORNELL UNIVERSITY MEDICAL COLLEGE, NEW YORK, U.S.A.

POSSIBLE MECHANISMS OF COMPLICATIONS OF ANGIOGRAPHY

by

H. KUTT, K. VEREBELY, N. BANG, I. STREULI and F. McDOWELL

Angiographic procedures employing water soluble iodinated contrast media are of great importance in clinical medicine. They are, however, associated with complications which range from mild subjective complaints to severe objective findings or death. The mild side effects are relatively frequent and have been reported to have an incidence of up to 33 % (PENDERGRASS et coll. 1955, FIELD et coll. 1962, CULP et coll. 1957). Severe complications, fortunately, are rare. Some contrast media have been found to be more toxic than others and the use of some earlier contrast media has been abandoned in favor of newer substances that have a lower incidence of complications.

The mechanisms of complications are not well understood. Some authors believe that all complications can be explained by mechanical factors such as faulty techniques or accidental dislodgement of a pre-existing atherosclerotic plaque or thrombus (SCHEINBERG & ZUNKER 1963). Others have found that contrast media have biological effects, which may in part be responsible for complications. Changes in capillary blood flow (SOBIN et coll. 1959, JOHNSON & KNISLEY 1962), capillary fragility, and increased capillary permeability have

been reported (FOLTZ et coll 1952 BASSETT et coll 1953, BROMAN & OLSSON 1949) The cardiac and respiratory rate have been found to be altered (EPSTEIN et coll 1959 GREITZ & WEISS 1959) A direct toxic effect upon cells has been thought to be responsible for certain complications (YERASIMIDES et coll 1963)

Our own studies have been concerned with the biological effects of contrast media on blood and its constituents and the possible relationships of such effects to the occurrence of complications The intravascular concentrations of contrast media during and following the injections for cerebral angiography have been measured This information was necessary for the evaluation and design of meaningful in vitro and animal experiments for demonstration of the biological effects of contrast media upon blood constituents At concentrations commonly encountered during angiography, changes in blood proteins red cells electrolytes and coagulation were found We believe that these changes may contribute to the development of certain types of complications

Materials and methods

Contrast media included in these studies were sodium diatrizoate, methyl glucamine diatrizoate (generously supplied by Winthrop Laboratories) sodium iothalamate methylglucamine iothalamate, sodium acetrizoate and iodopyracet

Patients included in these studies were individuals with a variety of neurologic disorders including many with cerebrovascular disease undergoing cerebral angiography for diagnostic purposes Also blood from young healthy volunteers was collected for controls of in vitro experiments

The intravascular concentrations of contrast media in the carotid artery during retrograde brachial angiography were measured with the help of a continuous sampling device previously reported from our laboratory The concentration of contrast medium in the carotid blood samples was determined with a phosphotungstic acid reagent or estimated from the dilution of Evans blue which had been previously mixed with the contrast media (KUTT et coll 1963)

Paper electrophoresis of blood proteins was carried out in Spinco Model R Durrum type paper electrophoresis cell with barbital buffers as previously reported (KUTT & MCDOWELL 1962) The strips were scanned with a recording densitometer Starch gel electrophoresis was carried out according to the technique of SMITHIES (1955)

The combined concentrations of ionized calcium and magnesium were determined with EDTA titration according to the technique of COULSEN & HERNANDEZ (cf GRADWOHL 1956)

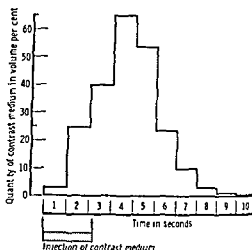


Fig 1 The dotted area represents quantities of contrast medium by volume in the common carotid area of a patient during retrograde brachial angiography A peak of 65 % by volume was reached in the 4th second after the start of injection The injection of 30 ml 50 % sodium diatrizoate lasted 2 2 seconds and is indicated by arrows

Counting red cell clumps was carried out in a specially designed counting chamber utilizing the principles of Breed counting The samples were prepared from 5 ml of venous blood collected into tubes containing EDTA as anticoagulant Six parts of blood were added to 4 parts of contrast medium, mixed on a Vortex Jr Mixer' for 5 sec and allowed to stand for 4 min and counted All counts were carried out within 30 min after drawing the blood and averages of 5 counts were calculated

The mesenteric circulation of albino male 300 gm rats of the Wistar strain previously anesthetized with 100 mg/kg of Nembutal given intramuscularly was studied Through a microscope the mesentery was observed on a horizontal observation stage while contrast medium was injected into the proximal stump of the carotid artery as previously reported (KUTT et coll 1963) This technique was adapted from ZWEIFACH and METZ (1956) Motion pictures of the mesenteric circulation were made before and after injection

The clotting time was determined according to the Lee White method A variety of components of the clotting system was determined according to the techniques of OWREN (1947), QUICK (1937) and BACHMANN et coll (1957)

The electrical conductivity of contrast media was measured in a LKB type 5313 conductolyzer flow cell with a Model RC 16B2 Industrial Instruments conductivity bridge

Results

Measurement of intravascular contrast medium concentrations during cerebral angiography in man Intraarterial and intravenous concentrations of contrast medium during and immediately after the injection of contrast medium were measured in 10 patients undergoing right retrograde brachial angiography Thirty ml

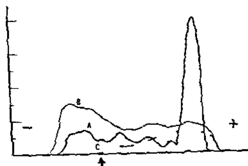


Fig 2 Densitometric recordings of paper electrophoresis patterns of normal serum protein (curve A) a mixture of 5 parts of serum and 5 parts of 50 sodium diatrizoate (curve B) and 50 sodium diatrizoate alone (Curve C)

contrast medium was injected into the innominate artery Sampling from the right common carotid artery revealed in one patient that as much as 65 % of its content for a few seconds consisted of contrast medium Fig 1 shows that the peak concentration of contrast medium was reached in the 4th second after the injection was started Then the concentration gradually fell to nearly zero within 9 seconds Peak values of about 50 % by volume of contrast medium were seen in 6 other patients In 3 patients peak concentrations of 35 to 40 % by volume were observed

A concentration of contrast medium of 72 % by volume for 1/2 second was found using a model which simulated the actual pressure and flow rate in the human carotid artery as might be present in a patient at the time of direct *carotid angiography* This suggests that during direct carotid angiography higher peak concentrations of contrast medium might occur *in cerebral blood than with brachial angiography*

Venous concentrations were measured in blood taken from the jugular bulb during and after the *injection of 30 ml of* contrast medium for retrograde brachial angiography Peak concentrations of 9 *to* 16 % by volume lasting 3 to 6 seconds were observed

These experiments indicated that considerable displacement of blood in the cerebral vessels takes place and the mixing ratios of blood and contrast medium in the carotid artery can be *as high* as 6 parts of contrast medium and 4 parts of blood

Changes of electrophoretic mobilities of blood proteins Mixing plasma serum, or whole blood with contrast media causes *changes in* the electrophoretic pattern of blood proteins The normal albumin and alpha and beta globulin peaks flattened and a high peak developed in the gamma globulin area These changes became more marked as the concentration of contrast media increased

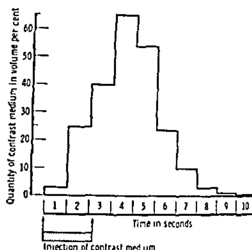


Fig 1 The dotted area represents quantities of contrast medium by volume in the common carotid area of a patient during retrograde brachial angiography A peak of 65 % by volume was reached in the 4th second after the start of injection The injection of 30 ml 50 % sodium diatrizoate lasted 2 2 seconds and is indicated by arrows

Counting red cell clumps was carried out in a specially designed counting chamber utilizing the principles of Breed counting The samples were prepared from 5 ml of venous blood collected into tubes containing EDTA as anticoagulant Six parts of blood were added to 4 parts of contrast medium, mixed on a 'Vortex Jr Mixer' for 5 sec and allowed to stand for 1 min and counted All counts were carried out within 30 min after drawing the blood and averages of 5 counts were calculated

The mesenteric circulation of albino male 300 gm rats of the Wistar strain previously anesthetized with 100 mg/kg of Nembutal given intramuscularly was studied Through a microscope the mesentery was observed on a horizontal observation stage while contrast medium was injected into the proximal stump of the carotid artery as previously reported (KUTT et coll 1963) This technique was adapted from ZWEIFACH and METZ (1956) Motion pictures of the mesenteric circulation were made before and after injection

The clotting time was determined according to the Lee White method A variety of components of the clotting system was determined according to the techniques of OWREN (1947), QUICK (1937) and BACHMANN et coll (1957)

The electrical conductivity of contrast media was measured in a LKB type 5313 conductolyzer flow cell with a Model RC 16B2 Industrial Instruments conductivity bridge

Results

Measurement of intravascular contrast medium concentrations during cerebral angiography in man Intraarterial and intravenous concentrations of contrast medium during and immediately after the injection of contrast medium were measured in 10 patients undergoing right retrograde brachial angiography Thirty ml

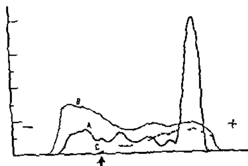


Fig 2 Densitometric recordings of paper electrophoresis patterns of normal serum protein (curve A) a mixture of 5 parts of serum and 5 parts of 50 sodium diatrizoat (curve B) and 50 sodium diatrizoate alone (Curve C)

contrast medium was injected into the innominate artery Sampling from the right common carotid artery revealed in one patient that as much as 65 % of its content for a few seconds consisted of contrast medium Fig 1 shows that the peak concentration of contrast medium was reached in the 4th second after the injection was started Then the concentration gradually fell to nearly zero within 9 seconds Peak values of about 50 % by volume of contrast medium were seen in 6 other patients In 3 patients peak concentrations of 35 to 40 % by volume were observed

A concentration of contrast medium of 72 % by volume for 1/2 second was found using a model which simulated the actual pressure and flow rate in the human carotid artery as might be present in a patient at the time of direct carotid angiography This suggests that during direct carotid angiography higher peak concentrations of contrast medium might occur in cerebral blood than with brachial angiography

Venous concentrations were measured in blood taken from the jugular bulb during and after the injection of 30 ml of contrast medium for retrograde brachial angiography Peak concentrations of 9 to 16 % by volume lasting 3 to 6 seconds were observed

These experiments indicated that considerable displacement of blood in the cerebral vessels takes place and the mixing ratios of blood and contrast medium in the carotid artery can be as high as 6 parts of contrast medium and 4 parts of blood

Changes of electrophoretic mobilities of blood proteins Mixing plasma serum or whole blood with contrast media causes changes in the electrophoretic pattern of blood proteins The normal albumin and alpha and beta globulin peaks flattened and a high peak developed in the gamma globulin area These changes became more marked as the concentration of contrast media increased

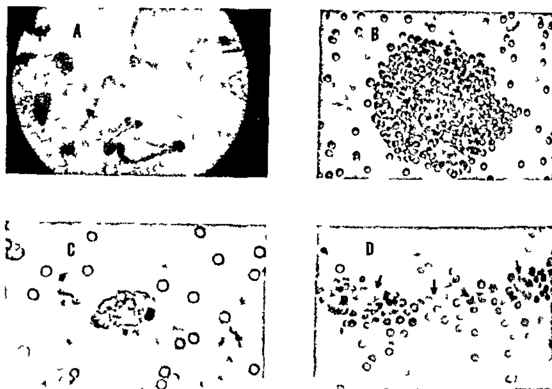
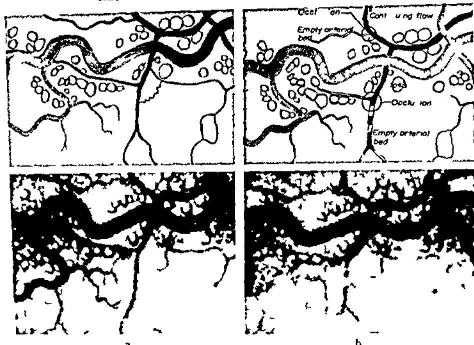


Fig 3 Photomicrographs of clumps formed in a mixture of 7 parts whole blood and 3 parts of 50 % *sodium diatrizoate A) Round oval and strand like clumps Magnification 8 × 2 5 B)* Round clump showing small clear area left from center Magnification 8 × 40 C) The clear center stained with bromphenol blue most of the red cells have been removed by crushing increased contrast over the unstained clear area in B D) Clear strand stained with bromphenol blue joining 2 round clumps with clear centers marked with arrows red cells partly removed by crushing

Fig 2 shows densitometer recordings of 1) a normal protein pattern (Curve A), 2) a mixture of 5 parts of serum and 5 parts of 50 % sodium diatrizoate (Curve B), and 3) 50 % sodium diatrizoate alone (Curve C) As can be seen, some protein in the mixture moved with the contrast medium faster than the albumin of unmixed serum, suggesting that the protein was bound to the contrast medium The majority of the protein moved towards cathode In starch gel electrophoresis, where the gel acts as a microfilter, all serum and contrast medium mixture components migrated slowly, suggesting an increase in the size of the moving particle, indicating aggregation These changes of electrophoretic migration pattern could be reversed by dialysis, suggesting that the major proteins were not denatured or permanently altered

Red cell clumping Clumps of red cells formed when blood was mixed with contrast medium These clumps were firm and their formation was enhanced by agitation of the mixture As can be seen in Fig 3 a variety of shapes of



F g 4 Frames from a mo ion film with schemat c drawings made of rat s mesentery before (a) and aft r (b) injection of 6 parts at blood and 4 parts 50 sodium diatr oate into aortic arch O lus ons and empty arter al beds

clumps were observed Some were round or oval others were elongated strand like structures and still others were round with elongated narrow processes In most of these clumps a clear amorphous central core could be demonstrated This stained blue when bromphenol blue was added to the mixture and could be clearly seen after red cell clumps had been crushed This indicated that the central core was a flake or strand of protein The central protein material also stained bluish with Mallory hematoxylin phosphotungstic acid stain (MALLORY 1942) suggesting that it contained fibrin The optimal concentration of contrast medium in blood for the formation of these clumps was 33 % by volume

Clumps were found in every blood sample of patients and controls studied by our technique However the number of clumps observed in 25 young healthy individuals ranged from 3 to 7 per chamber with an average of 5 for the whole group On the other hand the clump count of a patient on three different days who developed hemiparesis following cerebral angiography was 25 23 and 28

We have investigated the possibility that these clumps are capable of obstructing small blood vessels Rats were used in these studies because their

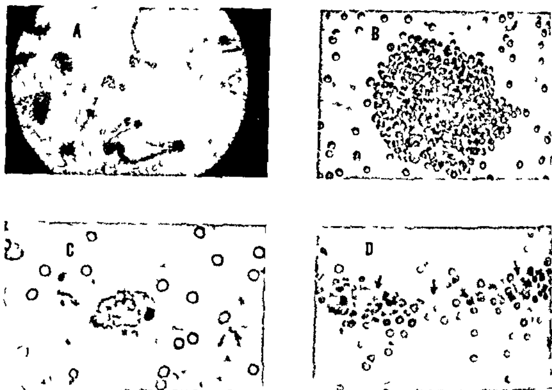


Fig 3 Photomicrographs of clumps formed in a mixture of 7 parts whole blood and 3 parts of 50 sodium diatrizoate A) Round oval and strand like clumps Magnification 8 × 25 B) Round clump showing small clear area left from center Magnification 8 × 40 C) The clear center stained with bromphenol blue most of the red cells have been removed by crushing increased contrast over the unstained clear area in B D) Clear strand stained with bromphenol blue joining 2 round clumps with clear centers marked with arrows red cells partly removed by crushing

Fig 2 shows densitometer recordings of 1) a normal protein pattern (Curve A), 2) a mixture of 5 parts of serum and 5 parts of 50 % sodium diatrizoate (Curve B), and 3) 50 % sodium diatrizoate alone (Curve C) As can be seen, some protein in the mixture moved with the contrast medium, faster than the albumin of unmixed serum, suggesting that the protein was bound to the contrast medium The majority of the protein moved towards cathode In starch gel electrophoresis, where the gel acts as a microfilter, all serum and contrast medium mixture components migrated slowly, suggesting an increase in the size of the moving particle, indicating aggregation These changes of electrophoretic migration pattern could be reversed by dialysis, suggesting that the major proteins were not denatured or permanently altered

Red cell clumping Clumps of red cells formed when blood was mixed with contrast medium These clumps were firm and their formation was enhanced by agitation of the mixture As can be seen in Fig 3, a variety of shapes of

Table 2

Comparison of the biological effects of various contrast medias

	Clump count in a mixture of 6 parts whole blood and 4 parts of 0.6 molar contrast medium	Number of ml of 0.6 molar contrast medium needed to produce tetany in rats	Coagulation defects in a mixture of 2 parts of plasma and 1 part of 0.6 molar contrast medium		Conductivity
			Quick test	*Factor V*	
Sodium diatrizoate	11	1.5—2.5 ml	8	40	180
Methylglucamine diatrizoate	0	9—11 ml	10	44	42
Sodium iothalamate	9	1.7—2.5 ml	9	40	170
Methylglucamine iothalamate	0	8—10 ml	9	45	46
Sodium acetrizoate	19	0.5—1.5 ml	0	4	200
Iodopyracet	17	2.5—3.0 ml	11	22	120

volume clotted slowly and mixtures of 50 % by volume did not clot. Addition of calcium ions shortened the Lee White clotting time somewhat, but did not bring it back to normal. Therefore other clotting factors were investigated.

Table 1 shows that several clotting factors and mechanisms were disturbed in a mixture of 7 parts blood and 3 parts sodium diatrizoate. The thrombin clotting time was prolonged 3 or 4 times more than the control. The accelerator globulin (Factor V) activity as estimated by the technique of OWREN was reduced to less than one fifth of that of the control. The activity of barium sulfate adsorbed plasma in the thromboplastin generation test was depressed to less than 1 %. This test in part reflects the activities of factors V and VIII.

Comparison of various contrast media. It was noted that the sodium compounds of contrast media constantly gave higher clump counts than the corresponding methylglucamine compounds. Therefore, equimolar solutions of available contrast media were prepared and their effects on clump counts, the amount needed to produce tetany in rats, and the disturbance of clotting factors were compared. Table 2 shows that the methylglucamine compounds of diatrizoate and iothalamate produced the least clumps, could be given in the largest amounts before causing tetany, and caused the least disturbances in clotting. The corresponding sodium compounds produced more marked changes

Table 1

Effects of sodium diatrizoate upon coagulation mechanisms

	Control mixture of 3 parts saline and 7 parts plasma	Mixtures of 3 parts 50 sodium diatrizoate and 7 parts plama
Thrombin clotting time (TCT)	28 sec	72—90 sec
Accelerator globulin (factor V as assayed by the method of Owren)	68 %	5—10 %
Activity of barium sulfate adsorbed plasma in thromboplastine generation test (TGT factors V VIII)	Normal	Less than 1 %

blood also formed clumps with the contrast media, and their mesenteric blood flow was easily observed Fig 4 shows frames from a motion film made during injection into the aortic arch of a mixture of 6 parts of rat blood and 4 parts of 50 % sodium diatrizoate Frame (a) was taken before the injection showing the relationship of venous and arterial branchings in the mesentery Frame (b) was taken of the same field after the injection There are obstructions visible at 2 bifurcations and empty arterial beds distal to obstructions While viewing the motion film, one could see stasis in an obstructed arterial branch and continuation of flow in other branches and in the veins These obstructions could still be seen after 2, 5 and 10 minutes following the injection

Tetany in rats During the studies of mesenteric circulation it was noted that the anesthetized rats became hyperexcitable after receiving 1 to 2 ml total of 50 % of sodium diatrizoate or sodium acetrizoate Touching the rat s nose or whiskers elicited jerking of all extremities and arching of the back After 4 to 5 ml of contrast medium had been introduced the jerking became spontaneous This tetanic state could be prevented by mixing 0 2 ml of 10 % calcium chloride solution with 1 ml of contrast medium Up to 12 ml of such mixtures could be given without the development of tetany Determinations of combined concentrations of ionized calcium and magnesium in the blood of tetanic rats by EDTA titration demonstrated a depression of these ions by 30 % as compared to control animals Determination of the combined concentrations of ionized calcium and magnesium in man from blood samples removed serially from the jugular bulb during carotid angiography showed a 25 % reduction during the peak contrast medium concentrations

Clotting defects It had been noted that the contrast medium and blood mixtures in which the concentration of contrast medium exceeded 30 % by

Table 2

Comparison of the biological effects of various contrast medias

	Clump count in a mixture of 6 parts whole blood and 4 parts of 0 6 molar contrast medium	Number of ml of 0 6 molar contrast medium needed to produce tetany in rats	Coagulation defects in a mixture of 2 parts of plasma and 1 part of 0 6 molar contrast medium		Conductivity
			Quick test	*Factor V*	
Sodium diatrizoate	11	1 5—2 5 ml	8 ∘	40	180
Methylglucamine diatrizoate	0	9—11 ml	10	44	42
Sodium iothalamate	9	1 7—2 5 ml	9	40 °	1[illegible]0
Methylglucamine iothalamate	0	8—10 ml	9	45	46
Sodium acetrizoate	19	0 5—1 5 ml	0	4	200
Sod pyr[illegible]cet	17	2 5—3 0 ml	11	22	120

volume clotted slowly and mixtures of 50 % by volume did not clot Addition of calcium ions shortened the Lee White clotting time somewhat but did not bring it back to normal Therefore other clotting factors were investigated

Table 1 shows that several clotting factors and mechanisms were disturbed in a mixture of 7 parts blood and 3 parts sodium diatrizoate The thrombin clotting time was prolonged 3 or 4 times more than the control The accelerator globulin (Factor V) activity as estimated by the technique of OWREN was reduced to less than one fifth of that of the control The activity of barium sulfate adsorbed plasma in the thromboplastin generation test was depressed to less than 1 % This test in part reflects the activities of factors V and VIII

Comparison of various contrast media It was noted that the sodium compounds of contrast media constantly give higher clump counts than the corresponding methylglucamine compounds Therefore equimolar solutions of available contrast media were prepared and their effects on clump counts the amount needed to produce tetany in rats and the disturbance of clotting factors were compared Table 2 shows that the methylglucamine compounds of diatrizoate and iothalamate produced the least clumps could be given in the largest amounts before causing tetany and caused the least disturbances in clotting The corresponding sodium compounds produced more marked changes

Table 1

Effects of sodium diatrizoate upon coagulation mechanisms

	Control mixture of 3 parts saline and 7 parts plasma	Mixtures of 3 parts 50 % sodium diatrizoate and 7 parts plasma
Thrombin clotting time (TCT)	28 sec	72—90 sec
Accelerator globulin (factor V as assayed by the method of Owren)	68 %	5—10
Activity of barium sulfate adsorbed plasma in thromboplastine generation test (TGT factors V, VIII)	Normal	Less than 1 %

blood also formed clumps with the contrast media, and their mesenteric blood flow was easily observed. Fig. 4 shows frames from a motion film made during injection into the aortic arch of a mixture of 6 parts of rat blood and 4 parts of 50 % sodium diatrizoate. Frame (a) was taken before the injection showing the relationship of venous and arterial branchings in the mesentery. Frame (b) was taken of the same field after the injection. There are obstructions visible at 2 bifurcations and empty arterial beds distal to obstructions. While viewing the motion film, one could see stasis in an obstructed arterial branch and continuation of flow in other branches and in the veins. These obstructions could still be seen after 2, 5 and 10 minutes following the injection.

Tetany in rats. During the studies of mesenteric circulation it was noted that the anesthetized rats became hyperexcitable after receiving 1 to 2 ml total of 50 % of sodium diatrizoate or sodium acetrizoate. Touching the rat's nose or whiskers elicited jerking of all extremities and arching of the back. After 4 to 5 ml of contrast medium had been introduced the jerking became spontaneous. This tetanic state could be prevented by mixing 0.2 ml of 10 % calcium chloride solution with 1 ml of contrast medium. Up to 12 ml of such mixtures could be given without the development of tetany. Determinations of combined concentrations of ionized calcium and magnesium in the blood of tetanic rats by EDTA titration demonstrated a depression of these ions by 30 % as compared to control animals. Determination of the combined concentrations of ionized calcium and magnesium in man from blood samples removed serially from the jugular bulb during carotid angiography showed a 25 % reduction during the peak contrast medium concentrations.

Clotting defects. It had been noted that the contrast medium and blood mixtures in which the concentration of contrast medium exceeded 30 % by

Table 2

Comparison of the biological effects of various contrast medias

	Clump count in a mixture of 6 parts whole blood and 4 parts of 0.6 molar contrast medium	Number of ml of 0.6 molar contrast medium needed to produce tetany in rats	Coagulation defects in a mixture of 2 parts of plasma and 1 part of 0.6 molar contrast medium		Conductivity
			Quick test	*Factor V*	
Sodium diatrizoate	11	1.5—2.5 ml	8	40	180
Methylglucamine diatrizoate	0	9—11 ml	10 °	44	42
Sodium iothalmate	9	1.7—2.5 ml	9	40 °	170
Methylglucamine iothalamate	0	8—10 ml	9 °	45	46
Sodium acetrizoate	19	0.5—1.5 ml	0	4	200
Iodopyracet	17	2.5—3.0 ml	11	22	120

volume clotted slowly and mixtures of 50 % by volume did not clot. Addition of calcium ions shortened the Lee White clotting time somewhat, but did not bring it back to normal. Therefore other clotting factors were investigated.

Table 1 shows that several clotting factors and mechanisms were disturbed in a mixture of 7 parts blood and 3 parts sodium diatrizoate. The thrombin clotting time was prolonged 3 or 4 times more than the control. The accelerator globulin (Factor V) activity as estimated by the technique of OWREN was reduced to less than one fifth of that of the control. The activity of barium sulfate adsorbed plasma in the thromboplastin generation test was depressed to less than 1 %. This test in part reflects the activities of factors V and VIII.

Comparison of various contrast media. It was noted that the sodium compounds of contrast media constantly gave higher clump counts than the corresponding methylglucamine compounds. Therefore equimolar solutions of available contrast media were prepared and their effects on clump counts, the amount needed to produce tetany in rats, and the disturbance of clotting factors were compared. Table 2 shows that the methylglucamine compounds of diatrizoate and iothalamate produced the least clumps, could be given in the largest amounts before causing tetany, and caused the least disturbances in clotting. The corresponding sodium compounds produced more marked changes

Table 3

Influence of dextran (molecular weight 60 000) upon the biological effect of 0.6 molar sodium diatrizoate

	Sodium diatrizoate	Sodium diatrizoate + 10 % dextran
Quick test	7 %	14 %
Factor V	36 %	48 %
Clump count	11	3
Amount needed for tetany in rats	1.5—2.0 ml	7.5—8.0 ml
Conductivity	175	114

Sodium acetrizoate caused the greatest changes in these factors of this group of contrast media. Iodopyracet, which is chemically less closely related to the media mentioned above, produced large numbers of clumps and markedly altered blood clotting.

Since the sodium compounds showed greater biological effects than the methylglucamine compounds, it was thought that the degree of ionization in these two groups could be different. Therefore, measurements of conductivity of these equimolar solutions were made. As can be seen in column 4 of Table 2, the conductivity of the sodium compounds was higher than the methylglucamine compounds. It was highest in sodium acetrizoate.

Effect of addition of albumin and dextran. The methylglucamine compounds which had low conductivity produced less biological effects, i.e. lower clump counts, less tendency to cause tetany, and somewhat smaller disturbances of the clotting mechanism, than sodium salts. It was thought that depression of ionization might be useful in further reducing the biological changes in blood. Since binding of contrast medium with protein was indicated by our earlier experiments we added purified human albumin to contrast media. Albumin added in amounts to produce a concentration of 10 to 15 % in the mixture reduced the conductivity, lowered the clump count, increased the amount that could be given before the appearance of tetany and decreased the defect in clotting. No obstructions were observed in the rat's mesenteric circulation with these mixtures. However, the mixtures were quite viscous with these concentrations of albumin. Dextran was also tested in the hope that it would bind with contrast medium and reduce its ionization and

biological activity Dextran (Dextran Clinical Grade, Henley Co New York, N Y) with a molecular weight of 60 000 was found to exert some beneficial effect if added in amounts to make a final concentration of 5 to 15 % Table 3 shows that the biological activity of both the sodium and methylglucamine compounds of diatrizoate were lowered by the addition of dextran The addition of dextran also caused a marked increase in the viscosity of the mixture No obstructions in the rats mesenteric circulation were observed with these mixtures Due to the high viscosity they could only be injected slowly

Discussion

Most water soluble contrast media have biological effects if given intravascularly in extremely large amounts and cause in vitro changes if used in high concentrations It is important to know the peak concentrations and the durations of various concentrations during angiographic procedures in humans When the in vivo and in vitro changes occur at concentrations known to exist in man one may attempt to connect those changes with certain complications

The mere displacement of blood going to the brain by contrast media may be of importance During angiography up to two thirds of the blood in the carotid artery may for a few seconds consist of contrast medium and this may cause a sufficient reduction of oxygen and other products to produce brain dysfunction Individuals particularly susceptible to this situation could be those whose brain already operates under unfavorable conditions such as vascular insufficiency increased intracranial pressure or a severe generalized metabolic disturbance The role of blood displacement by contrast media during angiography in the production of complications has yet to be investigated In instances with rapid circulation through the brain that effect would be negligible but in patients with cerebrovascular disease it could be significant

The changes of electrophoretic mobilities of protein suggest alteration of electrical charges and an increase in the size of the migrating particles This may be a contributory factor in the production of complications in patients whose blood already contains an abnormal protein such as occurs in patients with multiple *myeloma* and macro-globulinemia These patients are known to tolerate contrast media poorly and they are reported to have developed oliguria or anuria following urography In these patients at autopsy the kidney s tubules were found filled with protein casts (KILLMAN et coll 1957 PERRILLIE & CONN 1958) It is currently unknown whether these changes in serum protein are related to the complications of cerebral angiography

The mechanism of depression of calcium and magnesium ions is unclear but may be caused in part by substances added to the contrast medium for anticoagulation stabilization and buffering It also could be caused in part by in

creasing the binding of these ions to the altered protein Tetany in rats was caused by amounts of contrast media which are larger than those used in angiographic procedures in patients Yet since, in man, during arteriography up to two thirds of the intravascular volume can consist of contrast medium, seizures during or immediately following an injection could be related to displacement of blood and binding of these ions

The formation of red cell clumps in vitro has taken place with the blood of every individual tested according to the technique described We have observed the conjunctival vessels under a microscope of patients during angiography but have not seen definite clumps or permanent occlusions In rats, mesenteric vessels could be occluded by clumps It is likely that in most patients during angiography the clumps that may form cause no disturbance, however, in individuals with a marked tendency to form clumps, the microemboli may contribute to the occurrence of complications by blocking the micro circulation of the brain Such effects would be most marked in a diseased circulatory bed with a slow circulation time

The coagulation defect is probably caused by binding of contrast medium to coagulation factors The exact site of action is still unclear The various clotting factors seem to be affected in different degrees It is possible that a disturbance is created by interference with polymerization of fibrin monomers As a result of this, the formation of the normal fibrin network is delayed or does not take place, and abnormal fibrin fragments may develop These abnormal fibrin fragments may be part of the clear centers of clumps which can be stained with protein stains such as bromphenol blue and by fibrin stains such as Mallory's The role of a coagulation defect in the production of complications may be twofold On the one hand it may increase damage by hemorrhage in infarcted areas which may have developed through occlusion by red cell clumps On the other it may prevent intravascular clotting in areas of stasis and development of propagating thrombi in the collateral channels

There was a good correlation between the biological effects observed and electrical conductivity of contrast media Sodium compounds have the higher conductivity, and produced more changes than the methylglucamine compounds, indicating that the latter ionized to a lesser degree A further reduction of conductivity by the addition of albumin or dextran further reduced the biological effect However, the addition of albumin or dextran in effective amounts increased the viscosity considerably, making rapid injection difficult A smaller molecule would be preferable Since the biological effects seem to be proportional to the degree of ionization, it is likely that they are caused by binding of the ionized contrast medium molecules with protein molecules, perhaps through the carboxyl group of the benzoic acid radicale

It still must be established through further observations whether the biological alterations described by us are actually responsible for complications in patients during angiography It is of interest that sodium acetrizoate and iodopyracet produced the highest clump counts, the greatest disturbance of coagulation and produced tetany with smaller amounts than the diatrizoate and iothalamate compounds Iodopyracet and sodium acetrizoate have been abandoned for angiography because of the high incidence of unfavorable reactions

Acknowledgement

This work was supported by Research Grant HE 04872 05 from the National Heart Institute United States Public Health Service

SUMMARY

Contrast media exert biological effects upon blood components at concentrations that exist in blood vessels during angiography Effects observed were 1) replacement of blood 2) changes of proteins 3) clumping of red cells 4) depression of ionized calcium and magnesium levels and 5) clotting defects The possible relationship to complications is discussed Contrast media studied were sodium diatrizoate methylglucamine diatrizoate sodium iothalamate methylglucamine iothalamate sodium acetrizoate and iodopyracet All sodium compounds exerted stronger effects than methylglucamine compounds Addition of albumin or dextran before use diminished the intensity of biological effects

ZUSAMMENFASSUNG

Kontrastmittel erzeugen biologische Wirkungen gegenuber Bestandteilen des Blutes bereits in Konzentrationen die wahrend einer Angiographie in den Blutgefassen vorhanden sind Folgende Wirkungen wurden beobachtet 1) Verdrangung des Blutes 2) Eiweissveranderungen 3) Agglutinierung von roten Blutkorperchen 4) Verringerung des Spiegels von ionisiertem Calcium und Magnesium und 5) fehlerhafte Koagulation Die mogliche Verwandtschaft dieser Veranderungen mit Komplikationen wird besprochen Die untersuchten Kontrastmittel sind Natriumdiatrizoat Methylglukamindiatrizoat Natriumiothalamat Methylglukaminiothalamat Natriumacetrizoat und — iodopyrazet Alle Natriumverbindungen riefen starkere Wirkungen hervor als die Methylglukaminverbindungen Zusatz von Albumin oder Dextran vor Gebrauch verminderte die Starke der biologischen Wirkungen

RÉSUMÉ

Les moyens de contraste ont des effects biologiques sur les composants du sang à des concentrations qui existent dans les vaisseaux sanguins au cours de l angiographie Ces effets sont 1) le remplacement du sang par le moyen de contraste 2) des modifications des protéines 3) l agglomération des globules rouges 4) l abaissement du taux du calcium et du magnésium

creasing the binding of these ions to the altered protein Tetany in rats was caused by amounts of contrast media which are larger than those used in angiographic procedures in patients Yet since, in man, during arteriography up to two thirds of the intravascular volume can consist of contrast medium, seizures during or immediately following an injection could be related to displacement of blood and binding of these ions

The formation of red cell clumps in vitro has taken place with the blood of every individual tested according to the technique described We have observed the conjunctival vessels under a microscope of patients during angiography but have not seen definite clumps or permanent occlusions In rats, mesenteric vessels could be occluded by clumps It is likely that in most patients during angiography the clumps that may form cause no disturbance, however, in individuals with a marked tendency to form clumps, the microemboli may contribute to the occurrence of complications by blocking the micro circulation of the brain Such effects would be most marked in a diseased circulatory bed with a slow circulation time

The coagulation defect is probably caused by binding of contrast medium to coagulation factors The exact site of action is still unclear The various clotting factors seem to be affected in different degrees It is possible that a disturbance is created by interference with polymerization of fibrin monomers As a result of this, the formation of the normal fibrin network is delayed or does not take place, and abnormal fibrin fragments may develop These abnormal fibrin fragments may be part of the clear centers of clumps which can be stained with protein stains such as bromphenol blue and by fibrin stains such as Mallory s The role of a coagulation defect in the production of complications may be twofold On the one hand it may increase damage by hemorrhage in infarcted areas which may have developed through occlusion by red cell clumps On the other it may prevent intravascular clotting in areas of stasis and development of propagating thrombi in the collateral channels

There was a good correlation between the biological effects observed and electrical conductivity of contrast media Sodium compounds have the higher conductivity, and produced more changes than the methylglucamine compounds, indicating that the latter ionized to a lesser degree A further reduction of conductivity by the addition of albumin or dextran further reduced the biological effect However the addition of albumin or dextran in effective amounts increased the viscosity considerably, making rapid injection difficult A smaller molecule would be preferable Since the biological effects seem to be proportional to the degree of ionization, it is likely that they are caused by binding of the ionized contrast medium molecules with protein molecules, perhaps through the carboxyl group of the benzoic acid radicale

S HEI BERG P and ZUNKER E Complications in direct percutaneous carotid arteriography Arch Neurol 8 (1963) 676

S ITHIES O Zone electrophoresis in starch gels group variations in the serum proteins of normal adults Biochem J (1955) 629

SOBIN S S FRASHER W G JACOBSEN G and VAN EECKHOVEN F A Nature of adverse reactions to radiopaque agents preliminary report J Amer med Ass 170 (1959) 1546

YERASIMIDES T G MARGOLIS G and PONTON H J Prophylaxis of experimental contrast medium injury to the spinal cord by vasodepressor drugs Angiology 14 (1963) 394

ZWEIFACH B W and METZ D B Rat mesoappendix procedure for bioassay of humoral substances acting on peripheral blood vessels Ergebn Anat 35 (1956) 176

ionisés et 5) des lacunes par caillots Les auteurs examinent les rapports possibles entre ces effets et les complications Les moyens de contraste étudiés sont le diatrizoate de sodium le diatrizoate de méthylglucamine l iothalamate de sodium l iothalamate de méthylglucamine l acétrizoate de sodium et l iodopyracet Tous les composés sodés ont des effects plus intenses que les composés de la méthylglucamine L addition d albumine ou de dextran diminue l intensité des effets biologiques

REFERENCES

BACHMANN F et coll Differentiation of the factor VII complex Studies on the Stuart Prower factor Thrombos Diathes haemorrh 1 (1957) 169

BASSETT R C ROGERS J S CHERRY R C and GRUSHIT C The effect of contrast media on the blood brain barrier J Neurosurg 10 (1953) 38

BROMAN T and OLSSON O *Experimental study of contrast media for cerebral angiography* with references to possible injurious effects of cerebral blood vessels Acta radiol 31 (1949) 321

CULP D A VAN EPPS E F and EDWARDS C N Comparative studies of urographic media J Urol 78 (1957) 493

EPSTEIN J A HOFFMAN I and EPSTEIN B S Electrocardiographic alterations observed during percutaneous cerebral angiography Arch Neurol Psychiat 81 (1959) 142

FEILD J ROBERTSON J T and DESAUSSURE R L Jr Complications of cerebral angiography in 2 000 consecutive cases J Neurosurg 19 (1962) 775

FOLTZ L F THOMAS L B and WARD A A Jr Effects of intracarotid diodrast J Neurosurg 9 (1952) 68

GRADWOHL R B H *Clinical laboratory methods and diagnosis vol I 5th edition p 440* C V Mosby Co St Louis 1956

GREITZ T and WEISS S EEG and EKG in cerebral angiography with sodium diatrizoate (Hypaque) and methylglucamine diprotrizoate (miokon) Acta radiol 52 (1959) 145

JOHNSON J H and KNISLEY M H Intravascular agglutination of the flowing blood following the injection of radiopaque contrast media Neurology 12 (1962) 560

KILLMAN S GJORUP S and THAYSEN J H Fatal acute renal failure following intravenous pyelography in patients with multiple myelomata Acta med scand 1958 (1957) 43

KUTT H and MCDOWELL F Effects of iodinized contrast media upon electrophoretic mobilities of blood proteins and lipoproteins J Lab clin Med 59 (1962) 118

— MILHORAT T H and MCDOWELL F The effect of iodinized contrast media upon blood proteins electrolytes and red cells *Neurology 13 (1963) 492*

— SCHICK R W KENNIE L E and MCDOWELL F The quantities of sodium diatrizoate in cerebral vessels during arteriography J Neurosurg 20 (1963) 515

MALLORY F B Pathological technique 76 W B Saunders Co Philadelphia 1942

OWREN P A The coagulation of blood investigations of a new clotting factor Acta med scand Suppl 194 (1947)

PENDERGRASS E P et coll Further considerations of deaths and unfavorable sequelae following administration of contrast media in urography in the United States Amer J Roentgenol 74 (1955) 262

PERILLIE P E and CONN H O Acute renal failure after intravenous pyelography in plasma cell myeloma J Amer med Ass 167 (1958) 2

QUICK A J *Coagulation defect in sweet clover disease and in the hemorrhagic chick disease* of dietary origin Amer J Physiol 118 (1937) 260



Fig 1 Left anterior posterior angiograms Lateral displacement of internal carotid artery by aneurysm partially filled with contrast material

ry contusion with intra pulmonary hemorrhage The patient s respiratory distress improved but he developed considerable difficulty in swallowing and his voice became weak and hoarse Laryngoscopy revealed an area of ecchymosis on the left posterior pharyngeal wall weakness of the left side of the palate and a left vocal cord paralysis During the postoperative period the left pupil remained constricted The dysphagia gradually improved and the patient was discharged after 20 days of hospitalization

Throughout the next five months the left palatal weakness and the left vocal cord paralysis persisted Three months after discharge the patient began to complain of left occipital headaches and frequent vomiting At this time a tender mass was palpable high in the left side of the neck and fullness of the left tonsillar and pharyngeal areas was noted Six milliliters of thick old blood from the mass was aspirated through the left pharyngeal wall Shortly thereafter atrophy and fasciculations involving the left side of the tongue were observed It was felt that the mass probably represented an old hematoma related to the previous trauma

Physical examination On admission to The Johns Hopkins Hospital a firm tender 4 × 4 cm mass high in the left cervical area and partially under the angle of the mandible was palpated by intra and extraoral digital examination The mass pulsated but it could not be determined whether these pulsations were direct or transmitted The carotid artery was displaced laterally and anteriorly by the mass A bruit was heard over the mass There was some limitation of range of neck motion because of pain especially with involvement to the left The neurological examination revealed a left partial Horner s syndrome with miosis and ptosis The tongue deviated to the left and there was obvious atrophy and fasciculation of the

FROM THE DEPARTMENT OF RADIOLOGY AND NEUROSURGERY, THE JOHNS HOPKINS HOSPITAL, BALTIMORE, MARYLAND, U. S. A.

DISSECTING ANEURYSM OF INTERNAL CAROTID ARTERY AFTER NON-PENETRATING NECK INJURY

Case report

by

MAXWELL D. LAI, HARRY B. HOFFMAN and JOSEPH J. ADAMKIEWICZ

Dissecting aneurysms of the carotid vessels in the neck following penetrating injuries are well known. Non penetrating injuries resulting in vascular damage may lead to thrombosis. The purpose of this paper is to report an unusual case of cervical carotid artery dissecting aneurysm following a hyperextension neck injury sustained in an automobile accident.

Case report

History. A 21 year old white male was admitted to The Johns Hopkins Hospital with a chief complaint of pain in the left side of the head and neck of 6 months duration.

Six months previously he had been admitted to The Baltimore City Hospital some minutes after the automobile he was driving collided with a truck. He was conscious but restless and in a state of shock having a systolic blood pressure of 50 mm Hg. Multiple facial lacerations were noted but there was no evidence of trauma to the neck. Within 30 minutes his left pupil became constricted. *Because he was in shock a four quadrant paracentesis was performed* and blood was revealed in the left upper quadrant. At exploratory laparotomy a ruptured spleen was found and a splenectomy was performed. A chest film taken in the early postoperative period showed a fracture of the left ninth rib and a left pneumothorax. Because of increased respiratory distress a tracheotomy was performed. Subsequent chest films showed left pulmona

Discussion

This patient sustained an acute hyperextension neck injury as indicated by the history of an automobile accident, the cervical spine fracture, and lack of evidence of a penetrating injury. The subsequent development of a pulsating mass in the neck with multiple peripheral nerve deficits and a partial Horner's syndrome gave clues to the possibility of formation of a carotid artery aneurysm. The tracheal shift to the left and the relative enlargement of the left pyriform sinus were radiological signs compatible with the clinically known cranial nerve deficits. Carotid arteriography demonstrated the dissecting aneurysm of the internal carotid extending from the common carotid bifurcation to the base of the skull. The location and size of the aneurysm accounted for the involvement of the multiple cranial and cervical sympathetic nerves. Vertebral angiography was necessary to exclude involvement of this artery in the aneurysm and independent vertebral artery thrombosis. The left vertebral artery was small and probably hypoplastic. The superior half of this vessel was not demonstrated and thrombosis could not be excluded. At surgery there was no evidence of vertebral contribution to the aneurysm.

Carotid and vertebral arterial injuries following both penetrating and non penetrating neck trauma have been reviewed by SPUDIS et coll. (1962) as well as by GUARDJIAN et coll. (1963). Dissecting aneurysms of the cervical vessels following penetrating injuries have been well documented. The mechanism of formation consists of a local tear in the vessel wall leading to subintimal or medial dissection and subsequent incomplete or complete occlusion of the vessel lumen. The proximity of the arteries and veins in the neck make possible the formation of arteriovenous fistulas.

Examples of penetrating injuries besides stab or missile wounds of the neck include inadvertent laceration at the time of surgery (DENECKE 1958) and percutaneous carotid angiography (FLEMING & PARK 1959). Such injuries can also lead to thrombotic occlusion of the cervical vessels. Thrombus which forms at the site of intimal tear, may extend by forward propagation to occlude a long segment of the vessel.

Non penetrating neck injuries more commonly lead to thrombosis than to dissecting aneurysm. As in the case of penetrating injuries, the mechanism consists of a local intimal tear with thrombus formation. This occurred as shown by surgical exploration, in the third case reported by GUARDJIAN in which the patient sustained direct blunt trauma to the left anterior neck region. NORTHCROFT & MORGAN (1944) reported a fatal case of accidental hanging which led to dissection and complete occlusion. Thrombotic occlusion of portions of the vertebral basilar system following chiropractic manipulation has been reported by FORD & CLARK (1956).



Fig 2 Direct injection into aneurysm Numerous *blood clots outlined*

left side of the tongue The pharyngeal wall sagged on the left and did not rise with phonation although the gag reflex was present The left vocal cord was completely paralyzed There was weakness and partial atrophy of the left sternocleidomastoid and trapezius muscles

Roentgen examination In the cervical spine a small non displaced chip fracture involving the left uncinate process at the postero lateral margin of the upper surface of the C 7 vertebra was found The trachea was shifted to the left and the left piriform sinus was enlarged

A percutaneous left carotid cerebral angiographs revealed considerable lateral displacement of the internal carotid artery in the cervical region by a medially located mass The mass promptly filled with contrast medium and the lumen of the internal carotid was narrowed as it stretched over the lateral aspect of the mass (Fig 1)

A left selective vertebral angiographs performed by a brachial artery catheterization revealed a very small left vertebral artery Following aspiration of clotted blood from the mass contrast material was injected directly into the mass to define its limits (Fig 2)

The radiological diagnosis was a dissecting aneurysm of the extracranial portion of the left internal carotid artery extending from the common carotid bifurcation to the base of the skull

Operation A 4×6 cm dissecting aneurysm of the internal carotid artery was found The hypoglossal nerve was stretched over the aneurysmal sac The vagus nerve was completely adherent to its undersurface and the spinal accessory nerve was displaced backward and inferiorly The superior portion of the aneurysmal sac approached the base of the skull and thus precluded arterial replacement Therefore the external and internal carotid arteries were ligated and the aneurysmal sac was incompletely removed

Course The patient made an uneventful post operative recovery He has been followed one year without abnormal neurological findings other than those cranial nerve deficits present prior to surgery

Discussion

This patient sustained an acute hyperextension neck injury as indicated by the history of an automobile accident the cervical spine fracture and lack of evidence of a penetrating injury The subsequent development of a pulsating mass in the neck with multiple peripheral nerve deficits and a partial Horner s syndrome gave clues to the possibility of formation of a carotid artery aneurysm The tracheal shift to the left and the relative enlargement of the left pyriform sinus were radiological signs compatible with the clinically known cranial nerve deficits Carotid arteriography demonstrated the dissecting aneurysm of the internal carotid extending from the common carotid bifurcation to the base of the skull The location and size of the aneurysm accounted for the involvement of the multiple cranial and cervical sympathetic nerves Vertebral angiography was necessary to exclude involvement of this artery in the aneurysm and independent vertebral artery thrombosis The left vertebral artery was small and probably hypoplastic The superior half of this vessel was not demonstrated and thrombosis could not be excluded At surgery there was no evidence of vertebral contribution to the aneurysm

Carotid and vertebral arterial injuries following both penetrating and non penetrating neck trauma have been reviewed by SPUDIS et coll (1962) as well as by GUARDJIAN et coll (1963) Dissecting aneurysms of the cervical vessels following penetrating injuries have been well documented The mechanism of formation consists of a local tear in the vessel wall leading to subintimal or medial dissection and subsequent incomplete or complete occlusion of the vessel lumen The proximity of the arteries and veins in the neck make possible the formation of arteriovenous fistulas

Examples of penetrating injuries besides stab or missile wounds of the neck include inadvertent laceration at the time of surgery (DENECKE 1958) and percutaneous carotid angiography (FLEMING & PARK 1959) Such injuries can also lead to thrombotic occlusion of the cervical vessels Thrombus which forms at the site of intimal tear may extend by forward propagation to occlude a long segment of the vessel

Non penetrating neck injuries more commonly lead to thrombosis than to dissecting aneurysm As in the case of penetrating injuries the mechanism consists of a local intimal tear with thrombus formation This occurred as shown by surgical exploration in the third case reported by GUARDJIAN in which the patient sustained direct blunt trauma to the left anterior neck region NORTHCROFT & MORGAN (1944) reported a fatal case of accidental hanging which led to dissection and complete occlusion Thrombotic occlusion of portions of the vertebral basilar system following chiropractic manipulation has been reported by FORD & CLARK (1956)



Fig 2 Direct injection into aneurysm Numerous blood clots outlined

left side of the tongue The pharyngeal wall sagged on the left and did not rise with phonation although the gag reflex was present The left vocal cord was completely paralyzed There was weakness and partial atrophy of the left sternocleidomastoid and trapezius muscles

Roentgen examination In the cervical spine a small non displaced chip fracture involving the left uncinate process at the postero lateral margin of the upper surface of the C 7 vertebra was found The trachea was shifted to the left and the left piriform sinus was enlarged

A percutaneous left carotid cerebral angiography revealed considerable lateral displacement of the internal carotid artery in the cervical region by a medially located mass The mass promptly filled with contrast medium and the lumen of the internal carotid was narrowed as it stretched over the lateral aspect of the mass (Fig 1)

A left selective vertebral angiography performed by a brachial artery catheterization revealed a very small left vertebral artery Following aspiration of clotted blood from the mass contrast material was injected directly into the mass to define its limits (Fig 2)

The radiological diagnosis was a dissecting aneurysm of the extracranial portion of the left internal carotid artery extending from the common carotid bifurcation to the base of the skull

Operation A 4 × 6 cm dissecting aneurysm of the internal carotid artery was found The hypoglossal nerve was stretched over the aneurysmal sac The vagus nerve was completely adherent to its undersurface and the spinal accessory nerve was displaced backward and inferiorly The superior portion of the aneurysmal sac approached the base of the skull and thus precluded arterial replacement Therefore the external and internal carotid arteries were ligated and the aneurysmal sac was incompletely removed

Course The patient made an uneventful post operative recovery He has been followed one year without abnormal neurological findings other than those cranial nerve deficits present prior to surgery

REFERENCES

ANDERSON R McD and SCHECHTER M M A case of spontaneously dissecting aneurysm of the internal carotid artery J Neurol Neurosurg Psychiat 22 (1959) 195

DENECKE H J Zur therapie des traumatischen extrakraniellen Aneurysmas der Carotis int im Sauglingsalter mit Recurrens und Vaguslakmung HNO 7 (1958) 119

FLEMING J F R and PARK A M Dissecting aneurysms of the carotid artery following arteriography Neurology 9 (1959) 1

FORD F R and CLARK D Thrombosis of the basilar artery with softenings in the cerebellum and brain stem due to manipulation of the neck A report of two cases with one post mortem examination Reasons are given to prove that damage to the vertebral arteries is responsible Johns Hopk Hosp Bull 98 (1956) 37

GURDJIAN E L HARDY W G LINDNER D W and THOMAS L M Closed cervical cranial trauma associated with involvement of carotid and vertebral arteries J Neurosurg 20 (1963) 418

NORTHCROFT G B and MORGAN A D A fatal case of traumatic thrombosis of the internal carotid artery Brit J Surg 32 (1944) 105

SPUDIS E V SCHARYJ M ALEXANDER E and MARTIN J F Dissecting aneurysms in the neck and head Neurology 12 (1962) 867

An arteriosclerotic plaque is often mentioned as the site of origin of subintimal tear in both penetrating and non penetrating neck injuries Aortic arch dissections may also propagate into the cervical portion of the carotid arteries Spontaneous dissecting aneurysm involving the internal carotid artery in a case described by ANDERSON & SCHECHTER (1959) was explained by the presence of cystic medial necrosis

There were no findings in this case to suggest an associated vascular abnormality that predisposed the carotid artery to traumatic damage, since a complete review showed that this young patient was in excellent health The mechanism of formation of the dissection apparently was caused by a marked stretching of the vessel with subsequent intimal tear Instead of thrombosis, a false *passage developed in the vessel wall, leading to the formation of a large* dissecting aneurysm Still, the true lumen persisted to allow filling of the intracranial portion of the internal carotid

Acknowledgement

We wish to thank Dr Neal Aronson for his kindness in allowing us to use his patient and his encouragement in writing this case report

SUMMARY

A dissecting aneurysm involving the cervical portion of the left internal carotid artery occurred after acute hyperextension neck injury sustained in an automobile accident Following *the acute injury a pulsating mass associated with multiple peripheral* cranial nerve deficits and a partial Horner s syndrome appeared in the neck The definitive diagnosis was made by carotid angiography and the aneurysm was successfully treated by carotid ligation

ZUSAMMENFASSUNG

Ein dissekierendes Aneurysma das den Halsteil der linken Art carotis int umfasst trat nach akuter Hyperextensionsverletzung des Nackens als Folge eines Autounfalls auf Im Anschluss an die akute Verletzung trat eine pulsierende Schwellung auf Sie war begleitet von multiplen peripheren Hirnnervenausfällen und einem partiellen Horners Syndrom Die endgultige Diagnose wurde mittels Carotisangiographie gestellt das Aneurysma wurde *erfolgreich mit Carotisunterbindung behandelt*

RÉSUMÉ

Un anévrisme disséquant de la partie cervicale de la carotide interne gauche *est* apparu après une hyperextension cervicale brusque au cours d un accident d automobile Après la période aigue du traumatisme une masse pulsatile apparut dans le cou accompagnée de déficits périphériques de plusieurs nerfs craniens et d un syndrome partiel de Claude Bernard Horner Le diagnostic définitif a été fait par l angiographie carotidienne et l anévrisme a été traité avec succès par ligature de la carotide

REFERENCES

ANDERSON R McD and SCHECHTER M M A case of spontaneously dissecting aneurysm of the internal carotid artery J Neurol Neurosurg Psychiat 22 (1959) 195

DENECKE H J Zur therapie des traumatischen extrakraniellen Aneurysmas der Carotis int im Sauglingsalter mit Recurrens und Vaguslakmung HNO 7 (1958) 119

FLEMING J F R and PARK A M Dissecting aneurysms of the carotid artery following arteriography Neurology 9 (1959) 1

FORD F R and CLARK D Thrombosis of the basilar artery with softenings in the cerebellum and brain stem due to manipulation of the neck A report of two cases with one post mortem examination Reasons are given to prove that damage to the vertebral arteries is responsible Johns Hopk Hosp Bull 98 (1956) 37

GIARDJIAN E L HARDY W G LINDNER D W and THOMAS L M Closed cervical cranial trauma associated with involvement of carotid and vertebral arteries J Neurosurg 20 (1963) 418

NORTHCROFT G B and MORGAN A D A fatal case of traumatic thrombosis of the internal carotid artery Brit J Surg 32 (1944) 105

SPUDIS E V SCHARYJ M ALEXANDER E and MARTIN J F Dissecting aneurysms in the neck and head Neurology 12 (1962) 867

FROM THE METHODIST HOSPITAL, INDIANAPOLIS, INDIANA, U S A

COMPLICATIONS OF DIRECT AND INDIRECT ANGIOGRAPHY OF THE BRACHIOCEPHALIC VESSELS

by

ERICH K. LANG

The advent of surgical therapy for extracranial cerebrovascular disease necessitated new angiographic methods which would permit demonstration of the entire aortic arch and brachiocephalic vessels in various flexion and rotation positions of the head and neck. The advocation of catheter angiography for optimal demonstration of the structures as well as the increasing popularity of indirect brachial and axillary angiography challenges a comparison of the advantages and safety of these procedures with direct puncture of the carotid artery. This paper intends to evaluate the advantages and disadvantages of these various procedures and compare the relative safety of some 1 800 angiographies after direct puncture of the carotid artery to some *820 indirect* angiographies using the brachial or axillary approach and some 11 402 retrograde percutaneous catheter angiographies (9).

Carotid angiography after direct puncture is a technically simple procedure allowing excellent demonstration of the intracranial vessels. While this method offers the best detailed demonstration of these vessels, its chief disadvantage is inability to demonstrate the proximal portions of the brachiocephalic vessels and the aortic arch. Limitation of motion of the head and neck area after needle puncture prevents examination of the carotid and vertebral arteries in certain flexion and rotation positions of the head and neck.

Angiography after puncture of the brachial or axillary artery is likewise a technically simple procedure Right brachial angiography usually provides complete demonstration of the right carotid, cerebral and vertebrobasilar systems Left brachial angiography is used for the left vertebrobasilar system Demonstration of the left common carotid artery, however is quite difficult with this method and is accomplished in less than one third of all attempts The main disadvantage of this technique is the necessarily large amount of contrast medium which has to be injected to allow for proper filling of the aortic arch and the brachiocephalic vessels Isotope flow studies suggest a flow to the vertebral artery exceeding 25 % of the total amount injected whenever in excess of 30 ml of volume (10) Because of intolerance of brain to high concentrations of iodinated contrast media, substances used in this area have to be kept to less than twenty eight volume percent iodine content to avoid severe convulsive reactions These relatively low density contrast media render proper demonstration of the aortic arch difficult (12)

Retrograde percutaneous catheter angiography offers by far the most complete examination of this area (9) All brachiocephalic vessels can be engaged selectively and demonstrated in various flexion and rotation positions of the head and neck Homogeneous filling of the entire aortic arch with contrast medium is readily achieved by injection of a highly iodinated contrast medium into the ascending aorta Completely free motion of the head and neck area during the examination allows reproduction of any position that may aggravate or provoke the patient s condition The disadvantage of this method is the somewhat more complicated technique and time consuming procedure

Regardless of the risks involved certain conditions will dictate the preferential use of one or the other method Direct carotid needle angiography renders the best detail demonstration of the intracranial vessels Patients suspected of having vascular insufficiency, and particularly if symptoms become manifest in certain positions are best examined by retrograde catheter angiography This method alone is capable of answering all pertinent questions and producing a satisfactory demonstration of the arterial system in various extreme positions Indirect angiography from the brachial or axillary artery is particularly useful for the demonstration of the vertebrobasilar system The amount of contrast medium reaching the vertebrobasilar system can be carefully gauged and overflooding avoided The method is also used for panarteriography of the aortic arch

The choice of contrast medium is governed by the injection site Direct carotid or vertebral needle angiography is best carried out with 50 % diatrizoate sodium solution (Hypaque 50) 60 % meglumine iothalamate (Conray) or sodium and methylglucamine diatrizoates (Renovist) The amount of

FROM THE METHODIST HOSPITAL, INDIANAPOLIS, INDIANA, U S A

COMPLICATIONS OF DIRECT AND INDIRECT ANGIOGRAPHY OF THE BRACHIOCEPHALIC VESSELS

by

ERICH K. LANG

The advent of surgical therapy for extracranial cerebrovascular disease necessitated new angiographic methods which would permit demonstration of the entire aortic arch and brachiocephalic vessels in various flexion and rotation positions of the head and neck The advocation of catheter angiography for optimal demonstration of the structures as well as the increasing popularity of indirect brachial and axillary angiography challenges a comparison of the advantages and safety of these procedures with direct puncture of the carotid artery This paper intends to evaluate the advantages and disadvantages of these various procedures and compare the relative safety of some 1 800 angiographies after direct puncture of the carotid artery to some 820 indirect angiographies using the brachial or axillary approach and some 11 402 retrograde percutaneous catheter angiographies (9)

Carotid angiography after direct puncture is a technically simple procedure allowing excellent demonstration of the intracranial vessels While this method offers the best detailed demonstration of these vessels, its chief disadvantage is inability to demonstrate the proximal portions of the brachiocephalic vessels and the aortic arch Limitation of motion of the head and neck area after needle puncture prevents examination of the carotid and vertebral arteries in certain flexion and rotation positions of the head and neck

also the risks of the various procedures deserve to be evaluated properly The incidence rate of complications has varied greatly in various reported series (Table 4) This undoubtedly, depends on the quality of follow up and upon what each individual author chose to interpret as a complication (1, 3, 4 5 6 13 14 15 16 17 18)

An analysis of causative factors of complications readily identifies three factors pre existing conditions faulty technique, and complications associated with tissue toxicity of the contrast medium

For the purpose of comparative study complications are grouped into fatal complications serious complications and minor complications Minor complications differ from the more serious complications only quantitatively by their short duration and absence of late sequelae Serious complications may be severe reactions of transient nature or reactions resulting in a permanent deficit

Analysis of the material in the present series as well as previously reported series reveals certain common denominators Fatal reactions appear to be commonly linked to the underlying disease process The contributing force of the angiography to the ultimate demise of the patient remains questionable in many instances

Serious complications such as focal or generalized seizures hemiparesis hemiplegia unilateral dysesthesias visual field defects and language disorders of transitory or permanent nature appear to be greatly influenced by underlying vascular insufficiency and the amount and concentration of contrast medium used The potentiating effect of these two factors is also readily seen

The tissue toxicity of contrast media is related to their capillary concentration and preceding trauma to the effector tissue Hence vascular insufficiency will not only increase the capillary concentration but also render the effector tissue more susceptible

Patients with primary or metastatic brain tumors show a specific reaction to contrast media injection This may well be related to a change in the blood brain barrier in the tumor area and a specific reaction to the contrast medium

Focal and generalized convulsions appear to be directly related to the amount and concentration of contrast medium in the effector area Hence the amount of each injection the multiplicity of injections and the cerebral flow rate appear to be the main determining factor predisposing to such reactions Subintimal injections of contrast medium and resulting spasm of the arteries will tend to decrease the cerebral flow and hence increase the concentration of contrast medium in the capillary phase This is probably the mechanism by which convulsions may result from this technical difficulty (2) Transient aphasia and hemiparesis are likewise commonly seen following a subintimal

Table 1

Complications in 11 402 Seldinger procedures (Reprint from Radiology Vol 81 (1963) pp 257–263 Survey of the complications of percutaneous retrograde arteriography)

Fatal complications	7
Serious complications	81
Arterial thrombosis	47
(with secondary loss of limb)	6
Tip of guide wire or catheter broken	5
Perforation of major vessels with serious complications	13
Renal complications	2
Bowel ileus and necrosis	3
Minor complications	3[illegible]5
* Perforation of a major vessel with sequelae	2[illegible]
* Intramural or subintimal contrast injection witout sequela	136
* Local hematomas	167

* Temporary arterial spasm and loss of pulse were also observed in practically all patients with minor complications

contrast medium used for the injection of each carotid artery should not exceed *12 to 15 ml and 6 ml of contrast medium should be the upper limits for* verte bral studies

Indirect angiography is likewise best performed with media of low iodine content The amount used for each injection is considerably larger since a significant dead space is filled prior to overflow into the vertebral or carotid system Amounts up to 50 ml can be safely used Selective catheter angiography is also best performed with media of low iodine concentration The maximum amounts are similar to the recommended dosage in direct needle angiography Media of high iodine concentration such as sodium iothalamate 80 % (Angio Conray) and sodium and methylglucamine diatrizoates 90 % (Hypaque M 90) should only be used for injection into the ascending aorta and studies of the aortic arch Tissue toxicity and a specific effect upon the blood brain barrier limit the use of media of higher iodine concentration in the head and neck area (7)

Local anesthesia is usually preferred for indirect brachial and axillary *angiography and retrograde percutaneous catheter* angiography General anesthesia is commonly used for direct needle carotid and vertebral arterio graphy

Complications

The literature on cerebral angiography has repeatedly emphasized the values as well as the dangers of this diagnostic technique Since a choice of several techniques is offered to the physician not only their advantages but

Table 2 *(cont.)*

Reactions occurring in different angiographic examinations	Vertebral (430 cases)*	Aortic arch (325 cases)	Descending aorta (65 cases)
Serious complications			
Arterial thrombosis	4	4	—
Loss of limb	1	1	—
Convulsions	11	37	12
Large hematoma	1	2	7
Petechial skin hemorrhage	2	8	7
Ulnar paresis	1	—	—
Median nerve paresis	2	—	—
Pseudo-aneurysm at puncture site	2	1	1
Dissecting aneurysm of the brachial or the axillary artery	2	1	2
Subintimal dye injections	41	14	4
Extravasation of dye into the perivascular space	4	1	—
Pain persisting over 24 hours	3	4	2
Minor complications			
Hematoma	38	43	6
Temporary loss of pulse	382	286	60
Causalgia	1	—	—

2 deaths — Aneurysm of the basilar artery and cerebellar medulloblastoma

* Associated with perivascular extravasation of dye

patients with brain tumors This *is felt to represent* a well known reaction of patients with brain tumors to contrast media injection Focal or generalized convulsions were seen in 7 patients where inadvertent injection of the vertebrobasilar system with 12 ml of contrast medium was carried out In 32 other patients a review of the films revealed *either pre existing* extensive arteriosclerotic disease with vascular impairment or subintimal injection resulting in vascular spasm Hence a decreased cerebral *flow rate* and increased iodine content in the capillary phase is incriminated for the convulsive reaction Temporary hypoxia likewise may have *contributed to this reaction* In the third group — complications secondary to faulty technique — arterial thrombosis, abscess formation formation of large *retropharyngeal hematomas* and a thyrotoxic storm could be directly related to multiple traumatic punctures or faulty placement of the needle

Minor complications were numerous and most commonly caused by faulty

Table 2

Retrograde needle angiographies (820) (Survey compiled from 31 completed returns) In all cases the brachial artery or axillary artery was punctured with a No 17 or 18 thin walled needle

Type of examination	Patients	Contrast media	Amount ml	Pressure injection
A Vertebral angiography	430	Diatrizoate sodium 50 % (Hypaque 50) sodium iothalamate 80 % (Angio Conray) meglumine iothalamate 60 % (Conray) sodium and methy glycamine diatrizoates (Renovist)	15 to 30	Occasionally
B Aortic arch angiography	325	Diatrizoate sodium 50 % (Hypaque 50) sodium & methylglucamine diatrizoates (Hypaque M 90 %) sodium iothalamate 80 % (Angio Conray) medlumine iothalamate 60 % (Conray) sodium & methyglucamine diatrizoates (Renovist) diatrizoate methylglucamine 85 % (Cardiografin)	30 to 60	Yes
C Panarteriography	65	Diatrizoate sodium 50 % (Hypaque 50) sodium and methyl glucamine diatrizoates (Hypaque M 90 %) sodium and methylglucamine diatrizoates (Renovist) sodium iothalamate 80 (Angio-Conray) diatrizoate methyl glucamine (Renografin 60) Di Trnocon	50 to 80	Yes

injection of contrast medium and are probably direct consequences of the decreased cerebral flow rate and relative anoxemia

Carotid angiography after direct puncture The fatal complication rate in this series is slightly greater than 2 % However, the majority of these complications are probably not related to the angiographic procedure The underlying condition was such that the demise of the patient could be expected (Table 3)

The serious complications are readily divided into three groups Somnolence, progression of neurologic symptoms such as visual field defects, language disorders, hemiplegia and hemiparesis were observed in a large number of

Table 2 *(cont.)*

Reactions occurring in different angiographic examinations	Vertebral (430 cases)*	Aortic arch (375 cases)	Descending aorta ([illegible] cases)
Serious complications			
Arterial thrombosis	4	4	—
Loss of limb	1	1	—
Convulsions	11	37	12
Large hematoma	1	2	7
Petechial skin hemorrhage	2	8	7
Ulnar paresis	1	—	—
Median nerve paresis	2	—	—
Pseudo-aneurysm at puncture site	2	1	1
Dissecting aneurysm of the brachial or the axillary artery	2	1	2
Subintimal dye injections	41	14	4
Extravasation of dye into the perivascular space	4	1	—
Pain persisting over 24 hours	3	4	2
Minor complications			
Hematoma	38	43	6
Temporary loss of pulse	38[illegible]	28[illegible]	60
Causalgia	1	—	—

* 2 deaths — Aneurysm of the basilar artery and cerebellar medulloblastoma

** Associated with perivascular extravasation of dye

patients with brain tumors This is felt to represent a well known reaction of patients with brain tumors to contrast media injection *Focal or generalized* convulsions were seen in 7 patients where inadvertent injection of the vertebrobasilar system with *12 ml of contrast* medium was carried out In 32 other patients a review of the films revealed either pre existing extensive arteriosclerotic disease with vascular impairment or *subintimal injection* resulting in vascular spasm Hence a decreased cerebral flow rate *and increased* iodine content in the capillary phase is incriminated for the convulsive reaction Temporary hypoxia likewise may have contributed to this *reaction In* the third group — complications secondary to faulty technique — arterial thrombosis abscess formation formation of large retropharyngeal *hematomas* and a thyrotoxic storm could be directly related to multiple traumatic punctures or faulty placement of the needle

Minor complications were numerous and most commonly caused by faulty

Table 2

Retrograde needle angiographies (820). (Survey compiled from 31 completed returns.) In all cases the brachial artery or axillary artery was punctured with a No. 17 or 18 thin walled needle

Type of examination	Patients	Contrast media	Amount ml	Pressure injection
A. Vertebral angiography	130	Diatrizoate sodium 50% (Hypaque 50); sodium iothalamate 80% (Angio Conray); meglumine iothalamate 60% (Conray); sodium and methylglucamine diatrizoates (Renovist)	15 to 30	Occasionally
B. Aortic arch angiography	325	Diatrizoate sodium 50% (Hypaque 50); sodium & methylglucamine diatrizoates (Hypaque M 90%); sodium iothalamate 80% (Angio Conray); medlumine iothalamate 60% (Conray); sodium & methylglucamine diatrizoates (Renovist); diatrizoate methylglucamine 85% (Cardiografin)	30 to 60	Yes
C. Panarteriography	65	Diatrizoate sodium 50% (Hypaque 50); sodium and methylglucamine diatrizoates (Hypaque M 90%); sodium and methylglucamine diatrizoates (Renovist); sodium iothalamate 80% (Angio Conray); diatrizoate methylglucamine (Renografin 60); Di Triocon	50 to 80	Yes

injection of contrast medium and are probably direct consequences of the decreased cerebral flow rate and relative anoxemia.

Carotid angiography after direct puncture. The fatal complication rate in this series is slightly greater than 2%. *However, the majority of these complications* are probably not related to the angiographic procedure. The underlying condition was such that the demise of the patient could be expected (Table 3).

The serious complications are readily divided into three groups. Somnolence, progression of neurologic symptoms such as visual field defects, language disorders, hemiplegia and hemiparesis were observed in a large number of

Table 2 (con)

Reactions occurring in different angiographic examinations	Vertebral (430 cases)	Aortic arch (3[illegible]5 cases)	Descending aorta (65 cases)
Serious complications			
Arterial thrombosis	4	4	—
Loss of limb	1	1	—
Convulsions	11	37	1?
Large hematoma	1	2	3
Petechial skin hemorrhage	2	8	7
Ulnar paresis	1	—	—
Median nerve paresis *	2	—	—
Pseudo-aneurysm at puncture site	—	1	1
Dissecting aneurysm of the brachial or the axillary artery	2	1	2
Subintimal dye injections	41	14	4
Extravasation of dye into the perivascular space	4	1	—
Pain persisting over 24 hours	3	4	2
Minor complications			
Hematoma	36	43	6
Temporary loss of pulse	382	286	60
Causalgia	1	—	—

2 deaths — Aneurysm of the basilar artery and cerebellar medulloblastoma

Associated with perivascular extravasation of dye

patients with brain *tumors* This is felt to represent a well known reaction of patients with brain *tumors* to contrast media injection Focal or generalized convulsions were seen in 7 patients where inadvertent injection of the vertebrobasilar system with 12 ml of contrast medium was carried out In 32 other patients a review of the films revealed either pre existing extensive arteriosclerotic disease with vascular impairment or subintimal injection resulting in vascular spasm Hence a decreased cerebral flow rate and increased iodine content in the capillary phase is incriminated for the convulsive reaction Temporary hypoxia likewise may have contributed to this reaction In the third group — complications secondary to faulty technique — arterial thrombosis abscess formation formation of large retropharyngeal hematomas and a thyrotoxic storm could be directly related to multiple traumatic punctures or faulty placement of the needle

Minor complications were numerous and most commonly caused by faulty

Table 3

Complications encountered in 1 800 carotid angiographies all performed under general anesthesia (60 % were bilateral). Direct puncture technique with a modified Cournand No. 17 or 18 needle (long bevelled needles were used from 1951 through 1961, short bevelled since 1961). Hypaque 50 % was used 14 ml for unilateral and 28 ml for bilateral injections

Complication	Number
Death within 48 hours following procedure	
(none appeared to be necessarily related to the angiographic procedure although 5 tumor cases showed rapid progression of neurologic deficit following the examination)	
Aneurysm	22
Multiple trauma	8
Primary brain tumor	4
Metastatic brain tumor	3
Serious complications	
Arterial thrombosis (at puncture site)	2
Somnolence and progression of neurologic symptoms (92 of these were tumor cases)	96
Convulsions (7 inadvertent vertebral injections)	47
Abscess	1
Large hematoma (tracheotomy necessary)	1
Thyrotoxic storm (accidental injection into the superior thyroidal artery)	1
Minor complications	
Total number of extravasations	247
a) Subintimal injections	147
Without sequelae	132
Convulsions	3
Progression of neurologic symptoms (12 tumor cases)	14
Reversal of flow via the anterior communicating artery following a subintimal injection	22
Pain	110
b) Periarterial extravasation	124
Pain (23 with no comment on the presence or absence of pain in the clinical record)	101
Torticollis spasticus	1

placement of the needle. Particularly the long bevelled needle would often transfix the posterior wall of the carotid artery and result in subintimal contrast medium injections. Usually no late sequelae resulted. In many instances, the symptoms of the patient may have been of such minor significance that no specific record was made although some temporary transient neurologic degradation may have been present. Convulsions were recorded in only 3 % of the patients and these were minor in nature. A reversal of flow via the anterior communicating artery following subintimal contrast injection into one carotid artery was observed in 22 patients. This is felt to emphasize the hemodynamic significance of subintimal injections resulting in significant reduction of flow in the respective system. Pain was the most common manifestation of

Table 4

Complications from cerebral angiography in the literature

Authors	Angiogram obtained	Anesthesia	Mild	Complications Severe	Fatal	Contrast medium used
FEILD (6)	2332	92 Local	33	8	8	Hypaque 50
BULL (3)	1000	Not stated	Not stated	Not stated	3	Iodopyracet
SEGELOV (16)	660	General 1/3 Local 2/3	7	0	0	Diodrast 35 Urokon 30
CODDEN & KRIEGER (4)	546	Not stated	44	57	8	Diodrast 35 Urokon 70
WHITELEATHER (18)	7300	Local	0	2	0	Hypaque 50
PERESE (13)	234	General 1/4 Local 3/4	27	28	7	Diodrast 35
DUNSMORE (5)	147	Local	6	5	3	Diodrast 35
ABBOTT (1)	174	Not stated	2	17	5	Diodrast 35
SEDZIMIR (15)	273	General	0	0	0	Iodopyracet 42.5
SCHEINBERG (14)	902	Local	Not stated	34	3	Hypaque 50

subintimal injections observed in roughly 80 % of the patients. Periarterial extravasation was again most commonly associated with faulty technique and use of long bevelled needles. It is felt that the posterior wall of the artery was in most instances perforated during an attempt to advance and thread the needle. Flow was retained since only a portion of the bevelled needle had actually advanced beyond the lumen of the vessel. Pain was the most common and uniform complaint. With the exception of one patient who developed a torticollis spasticus no significant sequelae could be attributed to extravasation of contrast medium.

Indirect angiography. The fatal complications appear to be primarily related to underlying pre-existing conditions.

The serious complications are readily divided into two large groups. The first group is related to faulty technique. Arterial thrombosis, loss of limb formation of hematomas, ulnar and median nerve paresis, pseudo aneurysm at the puncture site, dissecting aneurysms of the brachial or axillary artery

and subintimal injections are the complications *encountered in this group*. It is noted that, although the use of damaging guide wires and catheters is eliminated by this technique, a substantial rate of arterial thrombosis is still observed. Undoubtedly, this is related to the experience of the operator and pre-existing arteriosclerotic conditions of the vessels.

The most significant complication appeared to be focal or generalized convulsions. The rate of convulsive reactions appeared to be directly proportional to the amount of contrast material used and hence to the concentration in the capillary phase of the vertebrobasilar system. Vertebral angiography utilizing a relatively small amount of contrast medium showed a rate of *convulsive reactions of slightly over 2 %. Arteriography of the aortic arch*, using an intermediate amount of 30 to 60 ml medium of low iodine concentration showed a rate of convulsive reactions of 11.5 %. Panarteriography, using up to 80 ml medium of high iodine concentration showed 18 % convulsive reactions. This appears to establish a causative relationship of relative concentration of iodine to convulsive reactions.

Minor complications were primarily related to local trauma to the arteries and inadequate compression of the puncture site with resulting hematoma formation.

Percutaneous retrograde catheter angiography. The fatal complication rate of 0.06 % in this survey is directly related to complications resulting from the angiographic procedure. This series encompasses angiograms of the head and neck area, the aortic arch, as well as the abdominal aorta. Fatal complications seen in a series primarily dealing with abdominal aortography will be less numerous since the common fatalities of brain tumors and cerebral aneurysms will not tend to weight such a series.

The serious complications are, likewise, primarily related to faulty technique and are not weighted by complications associated with primary vascular insufficiency of the cerebrovascular circulation, specific contrast medium *complications of these areas, and specific complications seen with* brain tumors. However, the common complication of arterial thrombosis at the puncture site using various techniques can be readily compared. Arterial thrombosis was seen in 0.11 % with direct needle puncture of the carotid artery and 0.4 % with Seldinger needle puncture for introduction of a percutaneous catheter, and in 1 % with indirect angiography after needle puncture of the brachial or axillary artery. Specific complications associated with the use of guide wire and catheters are arterial embolism secondary *to dislodgement* of arteriosclerotic plaques with the guide wire or catheter and breaking of tips of guide wires or catheters within the lumen of the vessel. Arterial

thrombosis is usually related to a combination of underlying vascular disease, poor vascular fitness and multiple traumatic punctures

Minor complications of this procedure are almost exclusively related to faulty technique such as multiple traumatic puncture poor local anesthesia traumatic advancement of the guide wire or catheter, or excessively long catheterization and inadequate compression of the puncture site after completion of the procedure

Major and serious complications can be avoided by careful selection of patients for these procedures and exclusion of patients with low output failure and poor vascular fitness, as well as early institution of anticoagulation therapy in some instances where the patient may be prone to arterial thrombosis at the puncture site because of predisposing conditions

Comments A critical analysis of the data reveals great difficulty in comparing the various figures The selective use of the various modalities governed by preexisting conditions groups the patient material according to underlying disease entities However it appears that direct carotid and vertebral needle angiography is an extremely safe procedure in the hands of the experienced operator The serious complication rate of arterial thrombosis at the puncture site 0 11 % compares well to 0 4 % seen in retrograde catheter angiography and 1 % in indirect angiography The increased complication rate of direct carotid angiography in patients in the older age group (6 Table 3) is undoubtedly related to arteriosclerotic disease and resulting difficulty in placement and threading of the needle Retrograde catheter angiography by selective techniques and indirect angiography will circumvent the difficulty of puncturing a severely diseased artery It is felt that a reduction of the injection flow rate and the amount of contrast material is also necessary to substantially decrease the complication rate in this group since only a combination of atraumatic introduction of contrast medium as well as maintenance of a safe capillary concentration will prevent convulsive reactions

Recommendations Carotid or vertebral angiography after direct puncture is recommended for the demonstration of the intracerebral vessels in detail

Retrograde percutaneous catheter angiography is recommended for selective demonstration of the brachiocephalic vessels in all patients with primarily arterial insufficiency syndromes and particularly those subject to positional aggravation Indirect angiography after puncture of the brachial or axillary artery may be substituted for this technique if severe arteriosclerotic disease renders the safe passage of catheters via the femoral artery difficult

The injection rate and amount as well as the concentration of contrast

and subintimal injections are the complications encountered in this group. It is noted that, although the use of damaging guide wires and catheters is eliminated by this technique, a substantial rate of arterial thrombosis is still observed. Undoubtedly, this is related to the experience of the operator and pre-existing arteriosclerotic conditions of the vessels.

The most significant complication appeared to be focal or generalized convulsions. The rate of convulsive reactions appeared to be directly proportional to the amount of contrast material used and hence to the concentration in the capillary phase of the vertebrobasilar system. Vertebral angiography utilizing a relatively small amount of contrast medium showed a rate of convulsive reactions of slightly over 2 %. Arteriography of the aortic arch, using an intermediate amount of 30 to 60 ml medium of low iodine concentration showed a rate of convulsive reactions of 11.5 %. Panarteriography, using up to 80 ml medium of high iodine concentration showed 18 % convulsive reactions. This appears to establish a causative relationship of relative concentration of iodine to convulsive reactions.

Minor complications were primarily related to local trauma to the arteries and inadequate compression of the puncture site with resulting hematoma formation.

Percutaneous retrograde catheter angiography. The fatal complication rate of 0.06 % in this survey is directly related to complications resulting from the angiographic procedure. This series encompasses angiograms of the head and neck area, the aortic arch, as well as the abdominal aorta. Fatal complications seen in a series primarily dealing with abdominal aortography will be less numerous since the common fatalities of brain tumors and cerebral aneurysms will not tend to weight such a series.

The serious complications are, likewise, primarily related to faulty technique and are not weighted by complications associated with primary vascular insufficiency of the cerebrovascular circulation, specific contrast medium complications of these areas, and specific complications seen with brain tumors. However, the common complication of arterial thrombosis at the puncture site using various techniques can be readily compared. Arterial thrombosis was seen in 0.11 % with direct needle puncture of the carotid artery and 0.4 % with Seldinger needle puncture for introduction of a percutaneous catheter, and in 1 % with indirect angiography after needle puncture of the brachial or axillary artery. Specific complications associated with the use of guide wire and catheters are arterial embolism secondary to dislodgement of arteriosclerotic plaques with the guide wire or catheter and breaking of tips of guide wires or catheters within the lumen of the vessel. Arterial

atteints de tumeurs cérébrales présentent souvent à la suite de l angiographie une aggravation de leurs signes neurologiques On pense que les réactions convulsives sont dues à la concentration relative en iode dans le lit capillaire et sont donc influencées par toute réduction du débit due à l artériosclérose grave ou à toute autre cause La prévention de l injection sous l intima évite des modifications brusques du débit L auteur recommande l angiographie carotidienne ou vertébrale directe pour l étude des vaisseaux intracérébraux Il réserve l angiographie percutanée rétrograde par cathétérisme au diagnostic des vaisseaux brachiocéphaliques soumis a des modifications posturales

REFFRENCES

1 Abbott K H Gay J R and Goodall R J Clinical complications of cerebral angiography J Neurosurg 9 (1952) 258

2 Brendler S J and Hayes G J Hypaque in cerebral angiography Report of complications in 617 angiograms J Neurosurg 16 (1959) 454

3 Bull J W D Cerebral angiography Postgrad med J 26 (1950) 157

4 Codden D R and Krieger H P Circumstances surrounding complications of cerebral angiography Analysis of 546 consecutive cerebral angiograms Amer J Med 25 (1958) 580

5 Dunsmore R Scoville W B and Whitcomb B B Complications of angiography J Neurosurg 8 (1951) 110

6 Feild G Robertson C T and DeSaussure G R Complications of cerebral angiography in 2 000 consecutive cases J Neurosurg 19 (1962) 775

7 Fleming G F Ross A and Park A Dissecting aneurysms of the carotid artery following arteriography Neurology 9 (1959) 1

8 Fujii K Grayson T Margulis A R and Saltzstein S Z The effects of intra arterial injection of contrast medias on canine intestine Amer J Roentgenol 89 (1963) 730

9 Lang E K Complications of percutaneous retrograde arteriography A survey Radiology 81 (1963) 257

10 — External internal carotid artery anastomosis and its correlation to RISA circulation studies Radiology To be published

11 Lattimer F R Webster J E and Gurdjian E S Complications of cerebral arteriography Grace Hosp Bull (Detroit) 30 (1952) 87

12 Marshall T R Ling J T and Gonzales R Additional experience with direct percutaneous noncatheter brachial arteriography — left panarteriography — right cerebral arteriography Radiology 81 (1963) 568

13 Perese D M Kite W C Bedell A J and Campbell E Complications following cerebral angiography Arch Neurol Psychiat (Chicago) 71 (1954) 105

14 Scheinberg P and Zunker E Complications of direct percutaneous carotid arteriography Arch Neurol 8 (1963) 676

15 Sedzimir C B Towards safer angiography J Neurosurg 12 (1955) 460

16 Segelov J N Safe angiography J Neurosurg 13 (1956) 567

17 Silverstein A and Krieger H P Complications of cerebral angiography A supplementary report J Mt Sinai Hosp 27 (1960) 1

18 Whiteleather J E and DeSaussure R L Experience with a new contrast medium (Hypaque) for cerebral angiography Radiology 67 (1956) 537

medium, should be correlated to the injection site, anticipated carotid, cerebral, or vertebrocerebral flow rates, underlying arteriosclerotic disease, and pre-existing conditions such as brain tumors.

Overinjection of the vertebral system should be avoided.

Meticulous and relatively atraumatic puncture of all vessels should be practiced.

Proper threading of short bevelled needle with the bevelled slant pointing to the posterior carotid wall should be used for carotid angiography to prevent subintimal injections, extravasation, and resulting changes in the arterial flow rate of the affected artery.

SUMMARY

The advantages, disadvantages, and complications of direct carotid, retrograde percutaneous catheter, and retrograde needle angiography are compared and analyzed. The fatal complications seen are usually related to pre-existing conditions, such as aneurysms, brain tumors, and so on. Patients with brain tumors often show aggravation of neurologic symptoms following angiography. Convulsive reactions are felt to be related to the relative iodine concentration in the capillary bed and hence are influenced by any reduction of flow rate due to severe arteriosclerotic disease or other causes. Prevention of subintimal injection will safeguard against sudden changes in flow rate. Direct carotid or vertebral angiography is recommended for the demonstration of the intracerebral system. Retrograde percutaneous catheter angiography is reserved for the diagnosis of the brachiocephalic vessels subject to positional changes.

ZUSAMMENFASSUNG

Die Vor- und Nachteile und Komplikationen von perkutanem retrogradem Carotiskatheter und retrograder Nadelangiographie werden verglichen und analysiert. Tödliche Komplikationen sind gewöhnlich zu bereits vorher existierenden Befunden, wie Aneurysmen, Hirntumoren und Ähnlichem in Beziehung zu setzen. Patienten mit Hirntumoren zeigen oft Aggravation von neurologischen Symptomen im Anschluss an eine Angiographie. Konvulsive Reaktionen scheinen mit der relativen Jodkonzentrationen in den Kapillaren in Beziehung zu stehen und werden durch jede Verminderung der Blutzirkulation infolge ernster Arteriosklerose oder anderen Ursachen beeinflusst. Die direkte Carotis- und Vertebralisangiographie wird zur Darstellung des intracerebralen Gefässystems empfohlen. Die retrograde percutane Katheterangiographie ist für die Diagnosstellung im brachiocephalen Gefässgebiet, das Lageveränderungen unterworfen ist, reserviert.

RÉSUMÉ

L'auteur examine et compare les avantages, les inconvénients et les complications de l'angiographie carotidienne directe, par cathétérisme percutané rétrograde et par ponction rétrograde à l'aiguille. Les complications mortelles sont habituellement rattachées à des affections pré-existantes tels que les anévrismes, les tumeurs cérébrales, etc. Les malades



Fig 1 Angiographie carotidienne droite Participation carotidienne à l irrigation d un angiome étendu à la fosse cérébrale postérieure et à l hémisphère cérébral droit



Fig 2 Angiographie vertébrale profil Angiome du vermis

La ventriculographie offrirait pour OLIVECRONA un aspect parfois évocateur image d allure marécageuse avec un defaut d injection du 4eme ventricule

Dans les deux cas ou nous l avons pratiquee la ventriculographie gazeuse a montre une dilatation ventriculaire globale avec un defaut d injection du 4eme ventricule et un refoulement lateral de l aqueduc de Sylvius Les 2 fois l intervention a confirme qu un hematome intra cerebelleux était à l origine de ces modifications radiologiques

Le bilan angiographique porte a la fois sur les systemes vertebral et carotidien

L angiographie carotidienne nous parait etre l examen a pratiquer d emblée en raison de sa simplicite et de l importance des renseignements apportés Ceux ci sont de 2 ordres

1 Elle objective la participation carotidienne a un angiome etendu non seulement a la fosse cerebrale postérieure mais a tout un hémisphere (Fig 1)

2 Dans un nombre non negligeable de cas elle permet de soupçonner l existence d une malformation de *petit volume* bien localisee et incite a pratiquer une angiographie vertébrale Nous avons rencontre cette eventualite a 4 reprises

Dans le premier cas l injection de la *cerebelleuse* superieure et de la cerebrale postérieure dessinait deja partiellement l angiome circumpédonculaire

Dans le deuxieme cas la cerebelleuse *supérieure* legerement injectée par l angiographie carotidienne montrait une tache floue dans un hémisphère cerebelleux suffisante pour prévoir la lesion

CLINIQUE CHIRURGICALE B (PROF P WERTHEIMER), HOPITAL NEUROLOGIQUE — SERVICE DE NEURO RADIOLOGIE (PROF AGRÉGÉ P BUFFARD), SERVICE DE NEURO CHIRURGIE (PROF J LECUIRE), UNIVERSITE DE LYON, FRANCE

ASPECTS RADIOLOGIQUES DES ANGIOMES DE LA FOSSE CEREBRALE POSTERIEURE

par

J LECUIRE, P BUFFARD, C LAPRAS, A GOUTELLE, J DUQUESNEL, D MICHEL, G FISCHER et J P DECHAUME

Les angiomes vrais ou anévrysmes artérioveineux de la fosse cérébrale postérieure sont moins bien connus que ceux de l étage sus tentoriel, mais le développement des techniques neuro radiologiques et la pratique courante de l'angiographie vertébrale permettent de préciser leurs caracteres

A propos d une série de 11 angiomes de la fosse cérébrale postérieure observés a Lyon au cours de ces 9 dernieres années, nous avons tenté d apprécier la valeur diagnostique des diverses investigations radiologiques radiographie simple du crane ventriculographie, angiographie carotidienne et surtout vertébrale

Les *signes fournis par la radiographie simple ont été nettement précises* par HOARE a propos de 3 cas 1) accentuation des empreintes vasculaires dans la partie postérieure de la voute osseuse, 2) élargissement des orifices vasculaires (canal *transversaire* de l atlas et de l axis, trou déchiré *postérieur*)

Dans nos observations, l'etude de ces modifications ne nous a pas fourni de renseignements de valeur



Fig 1 A g ographie carot d enne droite Parti cipation carotidienne à l irrigat on d un angiome étendu à la fosse cérébrale postérieure et à l hémi phere cérébral droit



Fig 2 Angiographie vertébrale profil Angiome du verm s

La ventriculographie offrirait pour OLIVECRONA un aspect parfois évocateur image d allure marécageuse avec un defaut d injection du 4eme ventricule

Dans les deux cas ou nous l avons pratiquee la ventriculographie gazeuse a montre une dilatation ventriculaire globale avec un defaut d injection du 4eme ventricule et un refoulement lateral de l aqueduc de Sylvius Les 2 fois l intervention a confirme qu un hématome intra cérébelleux etait à l origine de ces modifications radiologiques

Le bilan angiographique porte a la fois sur les systemes vertebral et carotidien

L angiographie carotidienne nous parait etre l examen à pratiquer d emblee en raison de sa *simplicité* et de l importance des renseignements apportes Ceux ci sont de 2 ordres

1 Elle objective la participation carotidienne a un angiome étendu non seulement à la fosse cerébrale postérieure mais a tout un hemisphere (Fig 1)

2 Dans un nombre non negligeable de cas elle permet de soupçonner l existence d une malformation de petit volume bien localisée et incite a pratiquer une angiographie vertebrale Nous avons rencontré cette éventualité a 4 reprises

Dans le premier cas l *injection* de la cerebelleuse supérieure et de la cerebrale posterieure dessinait deja partiellement l angiome circumpedonculaire

Dans le deuxieme cas la *cerebelleuse* superieure legerement injectee par l angiographie carotidienne montrait une tache floue dans un hémisphere cérebelleux, suffisante pour prevoir la lesion



Fig. 3. — Angiographie vertébrale profil. Angiome d'un hémisphère cérébelleux.



Fig. 4. — Angiographie vertébrale profil. Angiome étendu à la fosse cérébrale postérieure et à l'hémisphère droit.

Dans le troisième cas, la cérébelleuse moyenne visible sur l'artériographie carotidienne injectait en partie un angiome cérébelleux.

Dans le dernier cas enfin, l'existence d'une anastomose carotidobasilaire expliquait la visualisation d'un angiome circumpédonculaire sur l'angiographie carotidienne.

3. Enfin l'angiographie carotidienne apporte des données complémentaires très importantes lorsqu'elle permet d'étudier le jeu des anastomoses, les possibilités de suppléance et l'importance des pédicules issus des territoires sus-tentoriels.

L'angiographie vertébrale reste cependant l'examen qui objective avec le plus de précision les angiomes sous-tentoriels.

Elle peut être pratiquée selon diverses techniques que nous avons toutes utilisées : injection directe percutanée au niveau du canal transversaire, injection rétrograde par voie sous-clavière ou par cathétérisme selon la technique de Seldinger.

L'aspect de l'angiome est commun aux autres malformations cérébrales de même type, avec des pédicules artériels dilatés et souvent une dilatation du tronc de la vertébrale, un peloton vasculaire anormal et des veines de drainage dilatées et flexueuses, précocement injectées.

Il nous semble possible d'individualiser deux formes radiologiques qui correspondent aux formes anatomiques.

1. Les angiomes localisés aux hémisphères cérébelleux (Fig. 3) ou au vermis (Fig. 2).

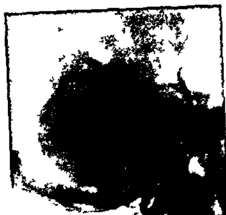


Fig 5 Angiographie vertébrale profil * Angiome circumpedonculaire

Ils sont nettement individualises relativement limites situés à la partie distale des vaisseaux Leurs pedicules artériels nourrissiers et leurs pédicules veineux efferents sont peu nombreux et peuvent etre précisés sur les angiographies Dans ce cas la tactique operatoire peut prevoir avant l intervention l approche de la malformation la recherche des pédicules arteriels et la preservation d au moins un pédicule veineux important avant l exérese complete

Ces conditions expliquent les possibilités chirurgicales et les bons resultats obtenus Dans notre serie 6 malades présentaient une telle localisation, 3 fois un traitement chirurgical a eté proposé et réalisé avec succes (exerese totale 2 fois ligatures vasculaires et evacuation d un hématome 1 fois)

2 Les angiomes du tronc cerebral sont moins bien individualises et leur analyse est difficile en raison des superpositions vasculaires et osseuses qui les masquent sur les diverses incidences

En effet certains angiomes du tronc cerebral interessent également les hemispheres cerebelleux ils apparaissent comme une vaste nappe floconeuse recouvrant tout ou partie de la fosse cerebrale posterieure et se projettent en surimpression sur les pédicules qui sont difficiles à systematiser du fait de la dilution du produit de contrast et de son passage extremement rapide dans la lesion (Fig 4)

D autres peuvent egalement s etendre à travers le trou occipital sur les premiers segments de la moelle cervicale sans hiatus entre les deux malformations

Les angiomes circumpédonculaires enfin representent une forme parti

culière des angiomes du tronc cérébral , bien que très limités, ils sont aussi difficiles à analyser , ils apparaissent mélangés au fouillis vasculaire et aux lacis des branches artérielles de cette région, intriquant la choroïdienne postérieure, la cérébelleuse supérieure et la cérébrale postérieure, nous en rapportons 3 cas (Fig 5), dont l'un fut opéré avec succès

L'angiographie vertébrale peut montrer également un refoulement des branches artérielles au pourtour de la lésion, signant l'existence d'un hématome intra parenchymateux associé , cet aspect n'est d'ailleurs bien individualisé que dans le cas des angiomes localisés aux hémisphères cérébelleux Inversement en effet il est difficile d'affirmer sur l'artériographie vertébrale l'existence d'un tel hématome dans le cas d'angiome du tronc cérébral étendu au cervelet, où la fosse cérébrale postérieure entière paraît recouverte d'un lacis vasculaire inextricable

En pratique, le choix des investigations neuroradiologiques dans les angiomes de la fosse cérébrale postérieure est guidé par les caractères de leurs manifestations cliniques qui peut revêtir trois aspects essentiels une hémorragie méningée (7 fois dans notre série), une néoformation de la fosse cérébrale postérieure (2 fois) et un syndrome vasculaire du tronc cérébral (2 fois)

La constatation d'une hémorragie méningée aboutira à un bilan vasculaire cérébral et en particulier à une angiographie vertébrale soit pratiquée à titre systématique, en l'absence de signes cliniques de localisation, soit justifiée par l'existence d'un tableau neurologique évocateur ou d'une image suspecte apparaissant déjà sur les angiographies carotidiennes

Dans la seconde éventualité, la scène clinique évoque une néoformation de la fosse cérébrale postérieure, dont rien ne permet de suspecter l'origine vasculaire malformative l'installation progressive ou rapide d'une hypertension intra crânienne avec oedème au fond d'oeil associée à un syndrome cérébelleux conduisent à une ventriculographie Les anomalies alors constatées — soit liées à la malformation elle même, soit liées à un hématome intra cérébelleux — font poser une indication opératoire qui redressera le diagnostic

Enfin, en présence d'un syndrome du tronc cérébral (syndrome de Parinaud ou syndrome alterne), l'existence d'un souffle intra crânien, la survenue d'un épisode méningé ou le caractère fluctuant de l'évolution pourront faire suspecter le diagnostic dont on demandera en définitive la confirmation à l'angiographie vertébrale

RÉSUMÉ

La connaissance des angiomes sous tentoriels repose essentiellement sur le bilan angiographique angiographie carotidienne permettant souvent de soupçonner la malformation et surtout angiographie vertébrale Celle ci individualise des aspects anatomiques opposés

Les angiomes limités au cervelet dont l angiographie detaille la disposition rendant possible une chirurgie d exérese Les angiomes du tronc sont d étude plus difficile surtout lorsqu ils intéressent toute la fosse postérieure Excepté l angiome circumpédonculaire bien localisé leur étendue interdit toute tentative chirurgicale

SUMMARY

Our knowledge concerning the subtentorial angiomas depends essentially on the angiographic findings Carotid angiography and especially vertebral angiography often permits us to suspect the presence of this malformation The latter examination can individualize opposed anatomical aspects Angiomas restricted to the cerebellum whose limits can be defined by angiography are thus rendered accessible for surgical excision Angiomas of the stem are more difficult to study especially when they involve the entire posterior fossa Except in the case of well localized circumpenduncular angiomas their extent forbids all attempts at tentative surgery

ZUSAMMENFASSUNG

Unsere Kenntnis der subtentorialen Angiome beruht im wesentlichen auf angiographischen Befunden Die Gegenwart solcher Angiome kann meistens nach der Carotisangiographie besonders aber nach der Vertebralangiographie vermutet werden Die letztere Untersuchung besonders kann die genaue Lokalisierung benachbarter anatomischer Gebiete klaren Es wird somit moglich Angiome die nur das Kleinhirn befallen zu erkennen und der chirurgischen Behandlung zugangig zu machen Es ist jedoch schwieriger die Angiome des Hirnstammes zu analysieren besonders wenn diese die ganze hintere Schadelgrube befallen Mit Ausnahme der Angiome die wohl abgegrenzt sich nur um den Hirnstamm ausbreiten ist die Chirurgie durchaus kontraindiziert

BIBLIOGRAPHIE

CASTELLANO F TROISI F e VITALI A Anevrismi arteriovenosi intracraniei del sistema vertebro-basilare Minerva neurochir 63 (1962) 103

CIMINELLO V J and SACHS E Arteriovenous malformations of the posterior fossa J Neurosurg 19 (1962) 607

CLÉMENT R GERVEAUX J COMBES-HAMELLE A PERTUISET B et PETRANCA C Anévrysmes artério-veineux de l ampoule de Galien chez nourrisson Leur role dans l hydrocéphalie non communicante Presse med 62 (1954) 658

COHEN M and KRISTIANSEN K Arteriovenous malformations of the great vein of Galen Neurology 4 (1954) 124

COLLMELLA F Considerazioni su 96 casi pathologici angiografia del sistema vertebro-basilare Chirurgia (Milano) 8 (1953) 250

CRAWFORD J W and RUSSEL D J Cryptio arteriovenous and venous hematomas of the brain J Neurol Neurosurg Psychiat 19 (1956) 1

DANDY W E Arteriovenous aneurysms of the brain Arch Surg 17 (1928) 190

FRENCH L A and PEYTON W T Vascular malformations in the region of the great vein of Galen J Neurosurg 2 (1954) 488

GALIBERT P et VEDRENNE C I Les anévrysmes artério veineux de la fosse postérieure Rapport Soc Neurochir Langue Franç , Lyon 1963

GIBSON J B TAYLOR A R and RICHARDSON A E Congenital arteriovenous fistula with an aneurysm of the great cerebral vein and hydrocephalus treated surgically J Neurol Neurosurg Psychiat 22 (1959) 224

GIBSON R M and DA ROCHA MELO A N Angiographic finding of an aneurysm and arterio venous malformation in the posterior cranial fossa in a case of subarachnoid haemorrhage J Neurol Neurosurg Psychiat 23 (1960), 237

GIRARD P BONNAMOUR G ROBERT J et LAPRAS C A propos d une observation d angiome à court circuit artério veineux de la calotte pédonculaire Lyon méd 17 (1958) 187

HOARE R D Arteriovenous aneurysm of the posterior fossa Acta radiol 40 (1953) 96

HOUDART R et LE BESNERAIS Y Les anévrysmes artério veineux des hémisphères cérébraux Masson Edit , Paris 1963

LINDGREN I Percutaneous angiography of the vertebral artery Acta radiol 33 (1950) 389

MCKISSOCK W RICHARDSON A and WALSH L Spontaneous cerebellar haemorrhage A study of 34 consecutive cases treated surgically Brain 83 (1960) 1

MARGOLIS G ODOM G L WOODHALL B and BLOOR B M The role of small angiomatous malformations in the production of intracerebellar hematoma J Neurosurg 8 (1951) 564

MORELLO G Angiomi della fossa posteriore Comm XIIème Congrès Soc It Neurochirur Rome 1960

NAYRAC L LAINE M , FONTAN M DELANDSHEER J M MME DELANDSHEER et GALIBERT P Étude clinique et thérapeutique de 2 volumineux anévrysmes artério veineux englobant le système de Galien Neuro chirurgie 2 (1956) 85

ODOM G L TINDALL G T and DUKES H T Cerebellar hematoma caused by angiomatous malformations J Neurosurg 18 (1961) 777

OLIVECRONA H and LADENHEIM J Congenital arteriovenous aneurysms of the carotid and vertebral arterial systems Springer Verlag Berlin 1957

POLLEN J L Vascular surgery of the posterior fossa Clin Neurosurg 6 (1959) 198

VERBIEST H Arteriovenous aneurysms of the posterior fossa Analysis of six cases Acta neuro-chir 9 (1961) 171

WERTHEIMER P ALLEGRE G LAPRAS C et NAGOULITCH I A propos de quelques aspects neuro chirurgicaux de la pathologie vasculaire cérébrale chez l enfant Neurochirurgie 4 (1961) 120

— TUSINI G LAPRAS C et THIERRY A A propos de huit observations cliniques d angiomes de la fosse cérébrale postérieure Comm XIIème Congrès Langue Franç Soc Neuro chir Lyon 1963 (A paraître)

WICKBOM I Angiographic examination of intracranial arteriovenous aneurysms Acta radiol 34 (1950) 385

SERVICES DE NEUROCHIRURGIE (PROF J LECUIRE) ET DE NEURORADIOLOGIE (PROF P BUFFARD), HOPITAL NEUROLOGIQUE ET CLINIQUE CHIRURGICALE B (PROF P WERTHEIMER) UNIVERSITE DE LYON FRANCE

CONSIDERATIONS SUR LES ASPECTS ANGIOGRAPHIQUES DES ABCÈS DU CERVEAU

par

J LECUIRE P BUFFARD A GOUTELLE A THIERRY J P DECHAUME et J KOFMAN

Le caractere clinique parfois trompeur des abces du cerveau ne permet pas toujours d évoquer d emblee un diagnostic dont l établissement ne souffre pourtant aucun retard l evolution de l abces peut etre marque comme l ont souligne BONNAL & DESCUNS par des aggravations rapides et imprévues Il semble donc essentiel de faire le diagnostic d'abcès sur l artériographie afin d affirmer la notion d urgence Nous avons repris le dossier radiologique de 45 abces du cerveau pour etudier les criteres angiographiques de l affection

L image en cocarde ou en anneau décrite par WICKBOM en 1948 puis par HEEP en 1949 nous a paru presenter un interet particulier Elle nécessite un examen minutieux sur les cliches secs en utilisant un spot lumineux

Il s agit d une image ronde ou oblongue formant un anneau peu dense parfois interrompu qui entoure une plage impregnée de façon moins marquée L examen à la loupe revele une impregnation fine et reguliere constituée de fines stries concentriques La plupart des auteurs ont insiste sur le caractere fugace de son apparition au cours de l arteriographie l utilisation du sério graphe montre qu une partie de la circonference commence à etre visible au

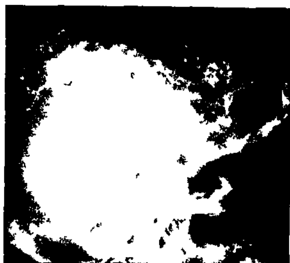


Fig. 1. — Artériographie carotidienne. Métastase cérébrale. Image en anneau.



Fig. 2. — Artériographie carotidienne. Refoulement des veines corticales dans un cas d'abcès frontal.

temps artériel. L'image apparaît cependant avec le maximum de netteté au premier temps veineux précoce où persiste encore un fin réseau capillaire.

Cet aspect est différent des images en anneau que donnent certaines métastases nécrosées en leur centre. Celles-ci comportent volontiers de petites dilatations veineuses périphériques (Fig. 1).

De même, dans certains gliomes du type V de WICKBOM, il est possible de rencontrer des images en anneau. Une étude soigneuse permet de retrouver souvent un ou plusieurs shunts artério-veineux.

L'image en cocarde nous paraît donc assez pathognomonique d'un abcès siégeant en plein parenchyme. Elle semble correspondre nullement à l'abcès lui-même. Elle a donné lieu à diverses interprétations pathogéniques résumées dans la thèse de LEMAN : elle résulterait de l'imprégnation de capillaires tassés en dehors de la coque vasculaire de l'abcès. LOMBARDI et coll. puis COLUMELLA en 1959 ont tenté de donner une valeur anatomopathologique à cette image qui traduirait une phase d'enkystement associée à une réaction péri-focale.

Sur le plan pratique, cette image se rencontre également dans les cas aigus et dans les cas chroniques. Nous l'avons observé dans des cas, où n'existait pas de coque et où le pus se trouvait dans une cavité constituée au sein d'un ramollissement cérébral. Son existence paraît donc due à la présence de pus franc, elle pourrait donc apparaître immédiatement après la phase d'encéphalite pré-suppurative.

Cette image n'est cependant pas constante, WEBER en 1960, ne trouve que 8 images en cocarde sur 51 observations d'abcès. BONNAL & DESCUNS ne la

mentionnent que 22 fois sur 212 cas Dans notre série, nous la retrouvons dans 48 % des cas ce qui constitue donc un pourcentage plus élevé

En l'absence de cet aspect caractéristique, l'angiographie cérébrale révèle une lésion expansive entraînant d'importants déplacements vasculaires comme l'avaient décrit pour la première fois MONIZ & LOFF en 1934

a) Les déplacements des gros troncs artériels sont particulièrement nets Les segments artériels étirés contrastent par leur aspect rigide avec les vaisseaux des régions saines qui ont conservé leur flexuosité normale

b) Le déplacement veineux intéresse non seulement les veines profondes mais également les veines corticales qui paraissent volontiers tendues sur une surface sphérique (Fig 2)

c) Dans l'écartement de ces vaisseaux une zone avasculaire est visible, surtout au temps capillaire

Quant aux aspects particuliers des abcès fronto sinusiens lorsque l'abcès est dû à une infection des sinus de la face, nous avons rencontré un aspect assez évocateur qui réalise sur le temps artériel une image en patte de crabe de la région frontale au temps capillaro veineux il s'agit d'une image avasculaire importante de la partie inférieure du lobe frontal avec bascule en arrière de l'angle veineux Cette image particulière semble correspondre à une suppuration de proche en proche qui refoule le lobe préfrontal tout en le détruisant

Enfin contrairement à certains auteurs, nous n'avons *jamais rencontré* les images de thrombose artérielle décrites par POUYANNE BONNAL DESCUNS et DUPLAY ont d'ailleurs fait la même constatation

En conclusion si le stade d'encéphalite *présuppuratiive semble* dépourvu de traduction radiologique l'abcès constitué *déforme généralement l'angio*gramme, l'artériographie carotidienne permet le plus souvent une localisation régionale précise surtout s'il existe la caractéristique image en cocarde La concordance entre les données anatomiques *et les aspects* radiologiques n'est cependant pas toujours parfaite

Un premier examen ne permet pas *toujours d'affirmer* la lésion et de poser une indication opératoire il faut savoir dans ce cadre pathologique répéter l'artériographie

En outre BLIGH & RACK ont *décrit* en 1962 trois cas où l'artériographie n'apporta aucun renseignement sur un *abcès* centro hémisphérique ce fut égalament le fait d'un de nos malades

Enfin devant un aspect de déplacement vasculaire sans image en cocarde, il est difficile d'apprécier les anomalies dues à l'abcès lui même, et les modifications qu'entraînent les réactions *oedémateuses périfocales*

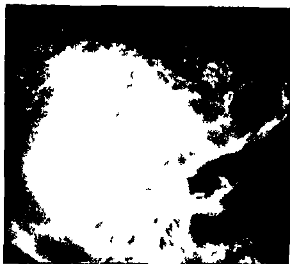


Fig. 1. — Artériographie carotidienne. Métastase cérébrale. Image en anneau.



Fig. 2. — Artériographie carotidienne. Refoulement des veines corticales dans un cas d'abcès frontal.

temps artériel. L'image apparaît cependant avec le maximum de netteté au premier temps veineux précoce où persiste encore un fin réseau capillaire.

Cet aspect est différent des images en anneau que donnent certaines métastases nécrosées en leur centre. Celles-ci comportent volontiers de petites dilatations veineuses périphériques (Fig. 1).

De même, dans certains gliomes du type V de WICKBOM, il est possible de rencontrer des images en anneau. Une étude soigneuse permet de retrouver souvent un ou plusieurs shunts artério-veineux.

L'image en cocarde nous paraît donc assez pathognomonique d'un abcès siégeant en plein parenchyme. Elle semble correspondre nullement à l'abcès lui-même. Elle a donné lieu à diverses interprétations pathogéniques résumées dans la thèse de LEMAN : elle résulterait de l'imprégnation de capillaires tassés en dehors de la coque vasculaire de l'abcès. LOMBARDI et coll. puis COLUMELLA en 1959 ont tenté de donner une valeur *anatomopathologique* à cette image qui traduirait une phase d'enkystement associée à une réaction péri-focale.

Sur le plan pratique, cette image se rencontre également dans les cas aigus et dans les cas chroniques. Nous l'avons observé dans des cas où n'existait pas de coque et où le pus se trouvait dans une cavité constituée au sein d'un ramollissement cérébral. Son existence paraît donc due à la présence de pus franc, elle pourrait donc apparaître immédiatement après la phase d'encéphalite pré-suppurative.

Cette image n'est cependant pas constante, WEBER en 1960 ne trouve que 8 images en cocarde sur 51 observations d'abcès. BONNAL & DESCUNS ne la

HEEP W Die Darstellung von Hirnabszessen in Phlebogram Zbl Neurochir 9 (1949) 2

LECLIRE J et D NY A Ventriculographie dans l abces du cerveau 19 observations Rev neurol 81 (1949) 395

LEMAN P L angiographie carotidienne dans les abcès du cerveau Thèse Medecine 117 Bordeaux 1953

LIMA P A Cerebral angiography Oxford Univ Press London 1950

LOMBARDI G and MIGLIAVACCA F Radiological considerations on cerebral abscesses Minerva Neurochir 3 (1959) 117

LUNDBERG N Diagnostik und Behandlung der Hirnabzesse Acta Oto-Laryng 29 (1941) 36

MANSUY L Quelques problemes de diagnostic et de traitem nt des abcès cérébraux Lyon Chir 52 (1956) 335

MONIZ E et LOFF R L épreuve angiographique dans le cas d abcès du cerveau Bordeaux Chir 1 (1934) 1

PENNYBACKER J B and CAWTHORNE T Discussion on diagnosis and treatment of cerebral abscess Proc roy Soc Med 38 (1945) 431

POUYANNE L POUYANNE H ARNE L et LEMAN P L angiographie cérébrale dans les abcès du cerveau (à propos de 6 observations) Rev neurol 85 (1951) 477

SCHURR P H Cerebral angiography in abscess of the temporal lobe Brit J Surg 39 (1951) 156

WEBER G L an iographie dans le diagnostic des abcès cérébraux Neuro-chirurgie 6 (1960) 317

WERTHEIMER P LECLIRE J LAFRAS C et TUSINI C Les abcès encéphaliques chez l enfant à propos de 16 observations Neuro-chirurgie 6 (1960) 373

WICKBOM I An ography of the carotid artery Acta radiol Suppl 72 Stockholm 1948

RÉSUMÉ

L'étude angiographique de 45 abcès du cerveau a permis de préciser l'importance des images en cocarde décrites par WICKBOM. Cet aspect visible dès le début du temps veineux paraît pathognomonique de l'abcès et indique la localisation avec une précision extrême. Il doit néanmoins être distingué d'images voisines rencontrées dans les gliomes ou les métastases nécrotiques. En son absence (52 % des cas) l'abcès se manifeste sur l'artériographie comme les autres lésions expansives.

SUMMARY

An angiographic study of 45 abscesses of the brain revealed the importance of the cockade like appearance described by WICKBOM. This appearance, which is visible from the beginning of the venous phase, seems to be pathognomonic of the abscess and indicates its site with great precision. It should however not be confused with similar appearances encountered in gliomas or in necrotic metastases. In its absence (52 % of cases) the abscess gives the same manifestations at angiography as other expanding lesions.

ZUSAMMENFASSUNG

Die angiographische Untersuchung von 45 Gehirnabzessen bestätigte die Bedeutung des von Wickbom beschriebenen Kokardezeichens. Dieses Zeichen kann von der venösen Frühphase an gut erkannt werden und kann als pathognomonisch für Gehirnabzess betrachtet werden; es führt genauen *Lokalisation des Krankheitsherdes. Man muss sich jedoch vor Verwechslung* mit ähnlichen Erscheinungen bei Gliomen und nekrotischen Metastasen hüten. Das Zeichen fehlt in 52 % der Fälle und man kann demgemäss lediglich einen raumbeschränkenden Prozess diagnostizieren.

BIBLIOGRAPHIE

BAGGIORE P. e BERTINI I. Possibilità angiografiche di diagnose e di prognosi negli ascessi cerebrali. Minerva Neurochir. 12 (1958) 158.

BARRE C. Aspect actuel des abcès du cerveau d'origine otitique et sinusienne. A propos de 8 cas. Thèse Médecine 626 Paris 1963.

BLICH A. S. and RACK P. M. H. Carotid angiography and cerebral abscess. J. Neurosurg. 19 (1962) 483.

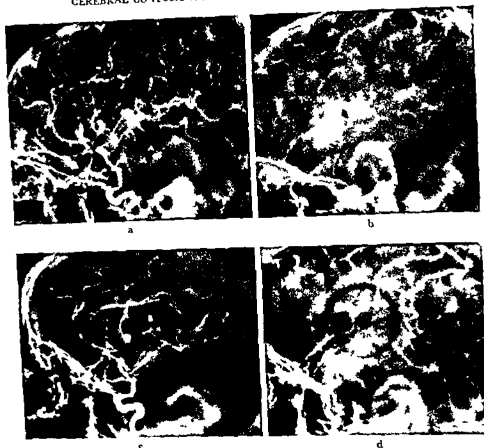
BONNAL J., DESCUNS P. et DUPLAY J. Les abcès encéphaliques à l'ère des antibiotiques. Etude statistique de 547 observations. Masson Edit. Paris 1961.

CHICHORRO V. L. L'angiographie dans les suppurations encéphaliques otorhinogenes. Rapport du XVII Congrès d'Oto-Neuro-Ophtalm. Lisbonne 1952. Institut Pasteur Edit. Lisbonne 1952, 79.

COLUMELLA F., DELZANO C. B. and NICOLA G. C. A propos of the angiographical circles in cerebral abscesses. Minerva Neurochir. 3 (1959) 119.

FABRITIUS H. F., FROVIG A. G. and KRISTIANSEN K. Percutaneous cerebral angiography and cerebral abscess. Arch. Neurol. Psychiat. 61 (1949) 352.

GERAUD J., LAZORTHES G., PICASSOU J. et ANDUZE H. L'angiographie cérébrale. J. Radiol. Électrol. 31 (1950) 141.



F g 1 P tient w th a tempo al lobe hematoma a) Spasm of supraclinoid portion of internal a ot d a tery (ne arrow) O g n of middle cereb al artery elevated and retrod splaced (two arrows) D ap ng of b anches of m ddle cereb al artery (A) suggesting an intrace ebral mass b) Abno mal collect on of veins in the venous phase (arrow) c) and d) Post operat ve arteriography No pasm bra ches of middle c ebral art ry a e now normal except for a local area of avascular ty due to ab ence of fill ng of a s ngle ascend ng f ontal branch of middle cerebral artery (B) wh ch may be secondary to previous su gery Th venous phase is normal

were an additional two films at one/sec The contrast material used was Hypaque 50 %

Clinical material There were 39 patients examined angiographically following head trauma None of the patients analyzed had significant subdural or epidural hematomas There were 4 patients with minimal subdural hematomas which may have been satellite hematomas The satellite or accessory hematoma has been described by COLUMELLA et coll (1963) as secondary to a

FROM THE DEPARTMENTS OF RADIOLOGY AND NEUROSURGERY OF THE LOS ANGELES COUNTY GENERAL HOSPITAL AND THE UNIVERSITY OF SOUTHERN CALIFORNIA SCHOOL OF MEDICINE, LOS ANGELES, U S A

ANGIOGRAPHIC CHANGES IN CEREBRAL CONTUSIONS AND INTRACEREBRAL HEMATOMAS

by

N E LEEDS, N D REID and I M ROSEN

We have analyzed the arteriograms performed on 39 patients with head trauma in whom a clinical diagnosis of cerebral contusion or intracerebral hematoma was suspected, but in whom no overt angiographic evidence of subdural or extradural hematoma was present The patients with subdural or extradural hematomas were excluded, because there have been several excellent papers on this subject (CARTON 1959, CRONQVIST & KOHLER 1963, NORMAN 1956, THOMPSON 1963)

The clinical indications for the performance of angiography following head trauma are (1) failure to improve or clinical deterioration, (2) localizing signs, (3) severe headache, and (4) the presence of papilledema

The value of angiography in these patients is underlined by the fact that there were only 2 normal bilateral carotid arteriographies and in an additional 2 patients there was only ventricular dilatation

Technique All the angiographies were performed utilizing a bi plane rapid serial film changer The sequence used was two films/sec for 2 sec and one film/sec for 4 sec If an elevation of intracranial pressure was suspected, there

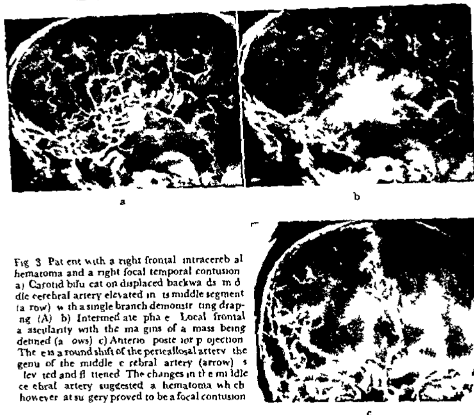


Fig 3 Patient with a right frontal intracerebral hematoma and a right focal temporal contusion a) Carotid bifurcation displaced backwards middle cerebral artery elevated in its middle segment (arrow) with a single branch demonstrating draping (A) b) Intermediate phase Local frontal avascularity with the margins of a mass being defined (arrows) c) Anterior posterior projection There is a round shift of the pericallosal artery the genu of the middle cerebral artery (arrow) is elevated and flattened The changes in the middle cerebral artery suggested a hematoma which however at surgery proved to be a focal contusion

in a local or a diffuse area Abnormal circulation was found in 2 cases (Fig 1) and local veins appeared early in one case The occurrence of an abnormal circulation or early filling veins in these patients is *due to a local hyperemia* secondary to focal cerebral hypoxia that may develop following head trauma (PITTS et coll 1964) *The local increase* in cerebral blood flow may lead to the shunting of blood with the *appearance of early* filling veins or an abnormal circulation

The local changes in circulatory dynamics will *not* aid in distinguishing a cerebral contusion from an intracerebral hematoma but will aid in accurately localizing the lesion

Arterial spasm The occurrence of arterial spasm following head trauma was first described by LOHR in 1936 Arterial spasm may be manifested by a localized (Fig 1 a and c) or diffuse (Fig 2) decrease in the calibre of the arterial lumen The arterial narrowing tends to be smooth and circumferential There

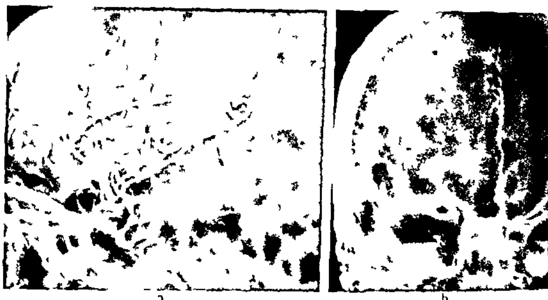


Fig. 2. Patient with extensive cerebral contusions bilaterally (a) and b) Extensive spasm of supraclinoid portion of internal carotid artery and of proximal anterior and middle cerebral arteries (arrow). Spasm also on opposite side, elevation of middle cerebral artery without draping, no shift of midline artery or of veins. (Left frontal fracture.)

cerebral laceration. These hematomas may be minimal, but on occasion may be significant.

There were 31 patients with contusions and 8 with intracerebral hematomas. Surgical or autopsy verification was established in 15 patients. These included 8 cerebral contusions, 6 intracerebral hematomas, and 1 post-traumatic encephalomalacia. There were 3 patients with minimal subdural hematomas; in 2 of these, there were cerebral contusions, and in 1 there was an intracerebral hematoma. A subdural hematoma may develop secondary to or coincident with any cerebral insult.

Lumbar punctures were performed in 34 of the 39 patients. Only 6 were normal. Twenty-seven patients had xanthochromic or bloody cerebrospinal fluid, while in one patient there was a traumatic lumbar puncture.

Skull films were obtained from 36 patients. Of these, 16 (44 %) revealed skull fractures. Two of the fractures were depressed.

Angiographic changes

Local circulatory changes. There were 17 (44 %) patients with an increase or decrease in local circulation (LEEDS & TAVERAS 1963). There was delayed filling of a local artery in 6 cases, delayed emptying in 2 cases, and local slowing in the intermediate (capillary) phase in 11 cases, or in the venous phase in 13 cases. This delay in filling in the intermediate and venous phases may occur

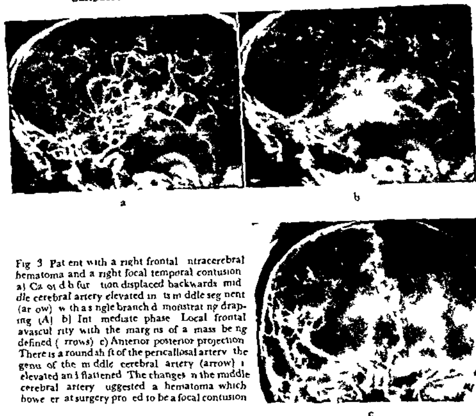


Fig 3 Patient with a right frontal intracerebral hematoma and a right focal temporal contusion a) Carotid bifurcation displaced backwards middle cerebral artery elevated in its middle segment (arrow) with a single branch demonstrating draping (A) b) Intermediate phase Local frontal avascularity with the margins of a mass being defined (arrows) c) Anterior posterior projection There is a round shift of the pericallosal artery the genu of the middle cerebral artery (arrow) is elevated and flattened The changes in the middle cerebral artery suggested a hematoma which however at surgery proved to be a focal contusion

in a local or a diffuse area Abnormal circulation was found in 2 cases (Fig 1) and local veins appeared early in one case The occurrence of an abnormal circulation or early filling veins in these patients is due to a local hyperemia secondary to focal cerebral hypoxia that may develop following head trauma (PITTS et coll 1964) The local increase in cerebral blood flow may lead to the shunting of blood with the appearance of early filling veins or an abnormal circulation

The local changes in circulatory dynamics will not aid in distinguishing a cerebral contusion from an intracerebral hematoma but will aid in accurately localizing the lesion

Arterial spasm The occurrence of arterial spasm following head trauma was first described by LOHR in 1936 Arterial spasm may be manifested by a localized (Fig 1 a and c) or diffuse (Fig 2) decrease in the calibre of the arterial lumen The arterial narrowing tends to be smooth and circumferential There

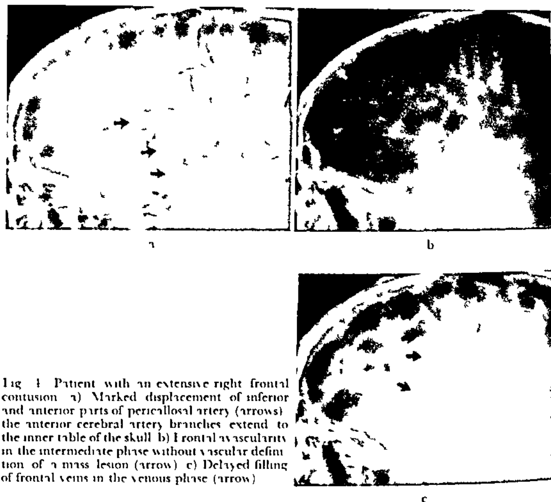


Fig. 1. Patient with an extensive right frontal contusion. a) Marked displacement of inferior and anterior parts of pericallosal artery (arrows); the anterior cerebral artery branches extend to the inner table of the skull. b) Frontal avascularity in the intermediate phase without vascular definition of a mass lesion (arrow). c) Delayed filling of frontal veins in the venous phase (arrow).

were 11 (31 %) of the patients with arterial spasm. In 10 (90 %) of the patients, there was bloody or xanthochromic spinal fluid. The etiology of the spasm is unknown except for the obvious relationship to the subarachnoid bleeding (COLUMELLA et coll. 1963, FREIDENFELT & SUNDSTRÖM 1963). The possibility of the increased sensitivity of an artery to contrast material has been suggested as a possible cause of the spasm (RAYNOR & ROSS 1960, TAVERAS & WOOD 1964).

Differential diagnosis

To determine the best mode of therapy, it is important to distinguish between a cerebral contusion and an intracerebral hematoma. The difficulty is that contusions may be focal, and in these cases the differentiation would be impossible, except that if follow up arteriography is performed at the end of 2 to 3 weeks, there should be a return to normal in patients with a contusion.



Fig 5 Patient with multiple cerebral contusions Spasm of supraclinoid portion of internal carotid artery The carotid bifurcation anterior cerebral artery and the proximal and insular segment of the middle cerebral artery are elevated spreading of the proximal ascending frontal branches of the middle cerebral artery in lateral projection Retrodisplacement of the pericallosal artery on the lateral film

A contusion will usually produce diffuse angiographic alterations while with a hematoma there will be focal changes (LINDGREN 1954)

Multiple angiographic lesions will usually indicate a *cerebral contusion* but there are patients with one area with an intracerebral *hematoma and* other areas of cerebral contusion (Fig 3)

A frontal contusion (Fig 4) may have an appearance similar to *an intra cerebral* hematoma except that in the hematoma (*Fig 3 c*) *a circumferential* artery or vein may be observed defining the *margins* of the mass lesion

In the temporal lobe the angiographic changes that distinguish a mass from a contusion *are the draping* sign (Fig 1 a and c) (CHASE & TAVERAS 1963) or the arterial *bowing that may* define the margins of the mass, but a focal contusion *may produce* similar changes (Fig 3a) Contusions usually produce diffuse changes (Fig 5)

Follow up arteriograms are *important to* evaluate any interval angio graphic changes that may *occur (resolution* progression or no change) There were 2 patients with *angiographic* evidence of resolution after an interval of 3 and 6 weeks and these were considered to have contusions because of the resolution after a relatively short interval (Fig 6) There was a patient in whom the follow up arteriogram demonstrated no change after 12 days At surgery *this* was a contusion Lack of change after a period of 1 to 2 weeks may be of no value in distinguishing a hematoma or contusion with post *traumatic* encephalomalacia

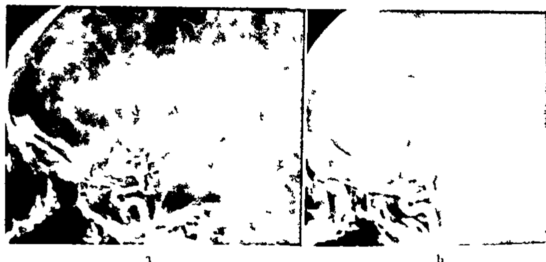


Fig. 6. Patient with a frontal opercular contusion. a) Spreading of the ascending fronto-parietal branches (A) of the middle cerebral artery. b) Four weeks later. Normal appearance of branches of the middle cerebral artery.

Generalized changes. There were 8 (21 %) patients with ventricular dilatation manifested by outward displacement of the thalamostriate vein on the anterior posterior projection in the venous phase. Two of these patients had normal sized ventricles at the first angiography with ventricular dilatation observed at a second angiography performed after an interval of 3 weeks. There were 2 (5 %) of the patients in whom the only angiographic alterations were ventricular dilatation, and only 2 (5 %) patients with normal angiograms.

SUMMARY

Angiographic changes were observed in 37 of 39 patients with severe head trauma (patients with overt evidence of subdural or extradural hematomas were excluded). Local variations in the rate of blood flow with increase or decrease in velocity were found in 17 patients. Arterial spasm was frequent. The angiographic changes that may aid in distinguishing cerebral contusions from intracerebral hematomas are discussed.

ZUSAMMENFASSUNG

Bei 37 von 39 Patienten mit schwerem Schadeltrauma wurden angiographische Veranderungen beobachtet (wobei Patienten mit klaren Anzeichen von sub und extraduralen Hamatom nicht mitgerechnet wurden). Lokale Variationen des Ausmasses der Blutzirkulation mit Beschleunigung oder Verlagsamung der Geschwindigkeit wurde bei 17 Patienten gefunden. Arterieller Spasmus war haufig vorhanden. Die angiographischen Veranderungen die bei der Differentialdiagnose zwischen cerebralen Kontusionen und intracerebralen Hamatomen mithelfen werden besprochen.

RÉSUMÉ

Des anomalies angiographiques ont été observées dans 37 traumatismes craniens graves sur 39 (les cas d hematomes sous-dural ou extra-dural évidents ont été exclus) Dans 17 cas on a constaté des variations locales en plus ou en moins de la vitesse circulatoire Le spasme artériel est fréquent. Les auteurs examinent les signes angiographiques qui peuvent aider à distinguer les contusions cérébrales des hématomes intracérébraux

REFERENCES

CARTON C A Cerebral angiography in the management of head trauma Charles C. Thomas Springfield Illinois 1959

CHASE N E and TAVERAS J M Temporal tumors studied by serial angiography A review of 150 cases Acta radiol 1 (1963) 225

COLUMELLA F DELZANNO G B GAIST G and PIAZZA G Angiography in traumatic cerebral lacerations with special regard to some less common aspects Acta radiol 1 (1963) 239

GRONQVIST S and KÖHLER R Angiography in epidural hematomas Acta radiol 1 (1963) 42

FREIDENFELT H and SUNDSTRÖM R Local and general spasm in the internal carotid system following trauma Acta radiol 1 (1963) 278

LEEDS N E and TAVERAS J M Changes in local circulation time in frontal and parietal tumors studied by rapid serial angiography Acta radiol 1 (1963) 332

LINDGREN E Handbuch der Neurochirurgie Vol II Röntgenologie Springer Berlin Gottingen Heidelberg 1954

LOHR W Hirngefassverletzungen im Arteriographischer Darstellung I Die Arteriographie bei Compressio Cerebri Zbl Chir 63 (1936) 2466

— Hirngefässverletzungen im Arteriographischer Darstellung II Thrombotische Verstopfungen und Zereissungen von Gefassen des Gehirns Zbl Chir 63 (1936) 2593

— Hirnarterienverletzungen in Arteriographischer Darstellung Zbl Chir 63 (1936) 3004

ORMAN O Angiographic differentiation between acute and chronic subdural and extradural hematomas Acta radiol 46 (1956) 371

PITTS F W HASKIN M F RIGGS H E and GROFF R A Tumor stain in cerebrovascular disease J Neurosurg 21 (1964) 298

RAYNOR R B and ROSS G Arteriography and vasospasm The effects of intracarotid contrast media on vasospasm J Neurosurg 17 (1960) 1055

TAVERAS J M and WOOD E H Diagnostic Neuroradiology Williams and Wilkins Co Baltimore Maryland 1964

THOMSON J L G Arteriography in head injuries Clin Radiol 14 (1963) 339



a b

Fig 6 Patient with a frontal opercular contusion a) Spreading of the ascending fronto parietal branches (A) of the middle cerebral artery b) Four weeks later Normal appearance of branches of the middle cerebral artery

Generalized changes There were 8 (21 %) patients with ventricular dilatation manifested by outward displacement of the thalamostriate vein on the anterior posterior projection in the venous phase Two of these patients had normal sized ventricles at the first angiography with ventricular dilatation observed at a second angiography performed after an interval of 3 weeks There were 2 (5 %) of the patients in whom the only angiographic alterations were ventricular dilatation, and only 2 (5 %) patients with normal angiograms

SUMMARY

Angiographic changes were observed in 37 of 39 patients with severe head trauma (patients with overt evidence of subdural or extradural hematomas were excluded) Local variations in the rate of blood flow with increase or decrease in velocity were found in 17 patients Arterial spasm was frequent The angiographic changes that may aid in distinguishing cerebral contusions from intracerebral hematomas are discussed

ZUSAMMENFASSUNG

Bei 37 von 39 Patienten mit schwerem Schädeltrauma wurden angiographische Veränderungen beobachtet (wobei Patienten mit klaren Anzeichen von sub und extraduralen Hämatom nicht mitgerechnet wurden) Lokale Variationen des Ausmasses der Blutzirkulation mit Beschleunigung oder Verlagsamung der Geschwindigkeit wurde bei 17 Patienten gefunden Arterieller Spasmus war häufig vorhanden Die angiographischen Veränderungen die bei der Differentialdiagnose zwischen cerebralen Kontusionen und intracerebralen Hämatomen mithelfen werden besprochen

RÉSUMÉ

Des anomalies angiographiques ont été observées dans 37 traumatismes craniens graves sur 39 (les cas d hématomes sous-dural ou extra-dural évidents ont été exclus) Dans 17 cas on a constaté des variations locales en plus ou en moins de la vitesse circulatoire Le spasme artériel est fréquent Les auteurs examinent les signes angiographiques qui peuvent aider a distinguer les contusions cérébrales des hématomes intracérébraux

REFERENCES

CARTON C A Cerebral angiography in the management of head trauma Charles C Thomas Springfield Illinois 1959

CHASE N E and TAVERAS J M Temporal tumors studied by serial angiography A review of 150 cases Acta radiol 1 (1963) 225

COLLMELLA F DELZANNO G B GAIST G and PIAZZA G Angiography in traumatic cerebral lacerations with special regard to some less common aspects Acta radiol 1 (1963) 239

CRONQVIST S and KOHLER R Angiography in epidural hematomas Acta radiol 1 (1963) 42

FREIDENFELT H and SUNDSTROM R Local and general spasm in the internal carotid system following trauma Acta radiol 1 (1963) 278

LEEDS N E and TAVERAS J M Changes in local circulation time in frontal and parietal tumors studied by rapid serial angiography Acta radiol 1 (1963) 332

LINDGREN E Handbuch der Neurochirurgie Vol II Rontgenologie Springer Berlin Gottingen Heidelberg 1954

LOHR W Hirngefassverletzungen in Arteriographischer Darstellung I Die Arteriographie bei Compressio Cerebri Zbl Chir 63 (1936) 2466

— Hirngefässverletzungen in Arteriographischer Darstellung II Thrombotische Verstopfungen und Zereissungen von Gefassen des Gehirns Zbl Chir 63 (1936) 2593

— Hirnarterienverletzungen in Arteriographischer Darstellung Zbl Chir 63 (1936) 3004

NORMAN O An io raphic differentiation between acute and chronic subdural and extradural hematomas Acta radiol 46 (1956) 371

PITTS F W HASKIN M E RIGGS H E and GROFF R A "Tumor stain" in cerebrovascular disease J Neurosurg 21 (1964) 298

RAYNOR R B and ROSS G Arteriography and vasospasm The effects of intracarotid contrast media on vasospasm J Neurosurg 17 (1960) 1055

TAVERAS J M and WOOD E H Diagnostic Neuroradiology Williams and Wilkins Co Baltimore Maryland 1964

THOMPSON J L G Arteriography in head injuries Clin Radiol 14 (1963) 339

FROM THE DEPARTMENTS OF RADIOLOGY AND NEUROSURGERY, E J MEYER MEMORIAL HOSPITAL AND THE STATE UNIVERSITY OF NEW YORK AT BUFFALO, BUFFALO, NEW YORK, U S A

THREE POSITIONAL PANCERVICAL ANGIOGRAPHY

by

EUGENE V LESLIE, GEORGE J ALKER JR and LOUIS BAKAY

A multitude of angiographic approaches to the problem of cerebrovascular disease are currently in vogue (1, 2, 5, 7, 9, 10, 11, 12, 13, 15, 16), most of them involving two or more arterial punctures, many not allowing demonstration of the aortic arch, and others not documenting the relationship of positional change to arterial narrowing We favor the examination of the surgically accessible arterial tree from the level of the aortic arch to the base of the skull by means of a single procedure, namely, aortic arch injection As an initial approach this allows one to determine the need for further investigation

In brief, our technique involves the percutaneous introduction of a No 8 teflon catheter into the ascending aorta via a femoral artery under local anesthesia Continuous EKG monitoring is done Three injections of 50 ml each of Hypaque 90 % are made, firstly with the head and neck straight but hyperextended, and then, still with extension, rotated to the left and to the right An effort is made to simulate any position specifically known to provoke symptoms Biplane studies were discarded as generally unrewarding

We prefer injection into the aorta because

1 This represents a single procedure which enables demonstration of all the surgically accessible arteries involved in cerebral blood flow, the difficulty in



Fig 1 Case 1 Normal three positional study

clinically distinguishing carotid from vertebro basilar from diffuse cerebro vascular disease (3 4 14) makes an examination of the entire vascular tree essential

2 The injection at this level allows one freely to utilize position changes to evaluate their effect on arterial lumen size

3 It permits multiple views of the great vessels

4 The procedure is better tolerated than direct injection of the carotid vertebral or brachial arteries

We prefer the femoral approach over use of one of the arteries of the arm because (1) the larger caliber artery results in fewer instances of vascular spasm or occlusion at or distal to the site of puncture (2) this is an easy puncture with a relatively low failure and complication rate

The axillary artery (7 10) however offers a good alternative in instances where a tortuous iliac artery or aorta cannot be catheterized from below

The three positional studies in addition to eliminating overlapping of some

FROM THE DEPARTMENTS OF RADIOLOGY AND NEUROSURGERY, E J MEYER MEMORIAL HOSPITAL AND THE STATE UNIVERSITY OF NEW YORK AT BUFFALO, BUFFALO, NEW YORK, U S A

THREE POSITIONAL PANCERVICAL ANGIOGRAPHY

by

EUGENE V LESLIE, GEORGE J ALKER JR and LOUIS BAKAY

A multitude of angiographic approaches to the problem of cerebrovascular disease are currently in vogue (1, 2, 5, 7, 9, 10, 11, 12, 13, 15, 16), most of them involving two or more arterial punctures, many not allowing demonstration of the aortic arch, and others not documenting the relationship of positional change to arterial narrowing We favor the examination of the surgically accessible arterial tree from the level of the aortic arch to the base of the skull by means of a single procedure, namely, aortic arch injection As an initial approach, this allows one to determine the need for further investigation

In brief, our technique involves the percutaneous introduction of a No 8 teflon catheter into the ascending aorta via a femoral artery under local anesthesia Continuous EKG monitoring is done Three injections of 50 ml each of Hypaque 90 % are made, firstly with the head and neck straight but hyperextended and then, still with extension, rotated to the left and to the right An effort is made to simulate any position specifically known to provoke symptoms Biplane studies were discarded as generally unrewarding

We prefer injection into the aorta because

1 This represents a single procedure which enables demonstration of all the surgically accessible arteries involved in cerebral blood flow, the difficulty in



Fig 1 Case 1 Normal three positional study

clinically distinguishing carotid from vertebro basilar from diffuse cerebro vascular disease (3 4 14) makes an examination of the entire vascular tree essential

2 The injection at this level allows one freely to utilize position changes to evaluate their effect on arterial lumen size

3 It permits multiple views of the great vessels

4 The procedure is better tolerated than direct injection of the carotid vertebral or brachial arteries

We prefer the femoral approach over use of one of the arteries of the arm because (1) the larger caliber artery results in fewer instances of vascular spasm or occlusion at or distal to the site of puncture (2) this is an easy puncture with a relatively low failure and complication rate

The axillary artery (7 10) however offers a good alternative in instances where a tortuous iliac artery or aorta cannot be catheterized from below

The three positional studies in addition to eliminating overlapping of some

Fig 2 Case 2 Marked stenosis of origin of left internal and external carotid arteries The three views show the lesion to best advantage

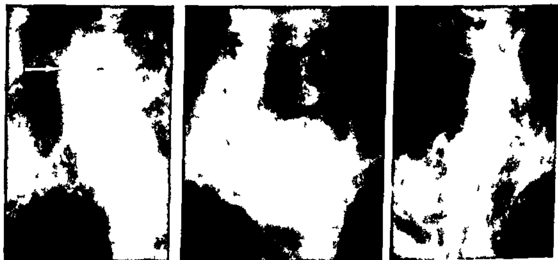


Fig 3 Case 3 Pre operative angiography The narrowing of the right vertebral artery by a large unco vertebral spur at C 5 6 is accentuated by rotation of the head to the right it disappears on rotation to the left Buckling of the left internal carotid artery occurs on rotation of the head to the left



F 4 Case 3 Post-oper tive angiography 8 months after anterior fusion at C 5—6 Normal caliber of ght vertebral artery n all three posit ons Buckling of the left internal carotid artery does not occ r this time when n ck was extended rather than flexed

of the vessels also permit demonstration of partial or complete temporary occlusion of one or both vertebral arteries by unco vertebral or apophyseal joint spurs Buckling of the carotid and verebral arteries may also be demon strated by this maneuver

This technique is of course no panacea and it has certain shortcomings namely

1 The demonstration of the intracranial vessels by this method is not wholly diagnostic because of relatively poor concentration of the contrast medium and considerable overlap of vessels This can be overcome by selective cath eterization (15) or direct percutaneous injection into the appropriate artery In any event normal neck vessels by no means exclude the possibility of intra cranial disease

2 Buckling is best demonstrated by using flexion while compression of vertebral arteries by unco vertebral spurs is best demonstrated by extension of the neck This would require at least two further views

3 Ante and post mortem angiographic studies indicate that clinical significance need not necessarily be attached to any specific angiographic lesion in the neck (3 14) Perhaps radioisotopic cerebral circulation studies will help us find the appropriate subjects for angiography

Material During the last few years we have carried out a total of 82 pancer vical angiograms in 78 patients 71 patients were catheterized successfully and there were 7 failures (9 %) Aside from one subintimal introduction of a

Fig 2 Case 2 Marked stenosis of origin of left internal and external carotid arteries The three views show the lesion to best advantage



Fig 3 Case 3 Pre operative angiography The narrowing of the right vertebral artery by a large unco vertebral spur at C 5—6 is accentuated by rotation of the head to the right it disappears on rotation to the left Buckling of the left internal carotid artery occurs on rotation of the head to the left



Fig 6 Case 4 Post-op rat e ang ograpy Only minimal indentation of the vertebral arteries at C 5—f the spurs hav ng regressed subsequent to the fusion Turning right and left no longer results in co np ess on of the lumen of either vertebral artery

the cervical portion of one or more of the carotid or vertebral arteries (in 9 patients one vessel was involved in 25 two vessels in 7 three, and in 5 four vessels)

Positional changes These included variation in the degree of buckling of arteries and of displacement or compression of the vertebral arteries by osteophytic spurs In 15 of those with spurs position change caused an increase in compression or displacement of an artery in 8 instances an occlusion in 1 and a decrease in compression or displacement of 9 arteries The caliber of an artery was sometimes decreased by rotation away from rather than toward that side suggesting the importance of the role of apophyseal joint spurring (8)

A variation in the degree of buckling with position change was encountered in 8 of 10 patients (13 vessels) who demonstrated either carotid or vertebral artery kinking when in the neutral position In no case was the caliber reduced below 50 %

Complications Seven complications (8 5 %) occurred in this series 1 scrotal hematoma 1 delayed local hematoma 2 vagovagal responses 2 depressed ST segments in the EKG 1 subintimal injection with back pain and shock Three of the major complications were associated with malfunction of a particular pressure syringe

The following illustrative cases are presented



Fig 5 Case 4 Pre operative angiography Displacement of right vertebral artery at C 4—5 and compression of both vertebral arteries at C 5—6 Rotation to right effects mild compression of *right vertebral artery at C 4—5 and marked compression at C 5—6 Rotation to left results in* occlusion of the small left vertebral artery

catheter, all failures occurred in patients over 65 years of age with extremely tortuous vessels Successful catheterizations, however, have been effected up to the age of 72 Satisfactory films were obtained in 73 of the 75 successful catheterizations (Four patients were examined twice)

Results

As with other published series, the yield of good surgical candidates was low (3, 6) Additionally there were two patients in this group with clinical cerebrovascular disease who had intra cranial tumor An artery was considered significantly abnormal angiographically if there was buckling, stenosis occlusion or displacement and compression by spurs In the vast majority the stenotic and occlusive disease was atherosclerotic in nature and involved the commonly encountered sites recorded by other authors (3, 14) The three cases of luetic or non specific arteritis showed involvement of the arch and the brachio cephalic vessels

Occlusive disease In 7 patients (10 %) there was involvement below the origins of the right common carotid and vertebral arteries One of these had occlusion of the origin of the left common carotid artery, this being considered an arch abnormality The subclavian artery was involved in 9 instances and the innominate artery in one A total of 46 patients (66 6 %) had involvement of

SUMMARY

Experiences with transfemoral three positional pancervical angiography are reviewed This in our opinion is the simplest best tolerated and most informative initial examination but it does not necessarily obviate the need for precise intra-cranial angiography Buckling of the carotid artery is of lesser significance than vertebral artery compression by osteophytic spurs Relief of the latter has in two of our patients been accomplished by anterior cervical fusion

ZUSAMMENFASSUNG

Unsere Erfahrung mit der drei positionalen pancervicalen Angiographie wird erlautert Diese stellt die einfachste am besten vertragliche und informative Untersuchung dar ohne dass sie eine genau durchgefuhrte intrakranielle Angiographie uberflussig macht Deformierungen der A carotis sind von geringerer Bedeutung als die Kompression der A vertebralis durch Osteophyten Letztere konnten bei zwei unserer Patienten durch eine anteriore cervicale Fusion beseitigt werden

RÉSUMÉ

Les auteurs tirent les conclusions de leur expérience de l angiographie pancervicale a trois positions par voie fémorale C est l examen initial le plus simple le mieux toléré et le plus instructif mais elle ne dispense pas toujours d une angiographie intracranienne précise Les tortuosités de la carotide ont moins d importance qu la compression de l artere vertébrale par des becs ostéophytiques Le traitement de cette compression a été fait chez deux des malades des auteurs par fusion cervicale antérieure

REFERENCES

1 AMPLATZ J RESCH J and HILAL S A catheter approach for cerebral angiography Radiology 81 (1963) 576
2 BANNISTER D G and MURRAY LESLIE R M Veno-angiography in cerebrovascular disease Brain 86 (1963) 161
3 BAUER R B SHEEHAN S WECHSLER N and MEYER J S Arteriographic study of sites incidence and treatment of arteriosclerotic cerebrovascular lesions Neurology 12 (1962) 698
4 FARIS A A POSER C M WILMORE D W and AGNEW C H Radiologic visualization of neck vessels in healthy men Neurology 13 (1963) 386
5 GURDJIAN E S HARDY W G LINDNER D W and THOMAS L H Four vessel angiography Experiences with three hundred consecutive cases Clin Neurosurg 10 (1964) 251
6 — LINDNER D W HARDY W G and THOMAS L H Incidence of surgically treatable lesions in cases studied angiographically Neurology 11 (1961) 150
7 HANAFEE W Axillary artery approach to carotid vertebral abdominal aorta and coronary angiography Radiology 81 (1963) 559
8 KOVACS A Subluxation and deformation of the cervical apophyseal joints Acta radiol 43 (1955) 1

Case 1 (normal) L. K., a 58 year old Indian male with rheumatic heart disease was investigated for possible occlusive cerebrovascular disease. His *three positional pancervical angiogram* (Fig. 1) was essentially normal. The origins of the vessels, the carotid bifurcations and the entirety of the surgically accessible cerebral arterial supply were demonstrated. The neutral right and left rotation series provided multiple views, avoided overlap and elucidated any effect of position change on arterial lumen size. Serial filming occasionally obviates overlap also, especially of the vertebral artery origin.

Case 2 (occlusive disease) G. C., a 66 year old white male with symptoms of cerebrovascular insufficiency showed stenosis of the left internal and external carotid arteries (*Fig.* 2). The multiple views aided in delineating the extent of the process and obviated overlapping.

Case 3 (vertebral artery compression and carotid buckling) S. W., a 42 year old colored male had complaints of dizziness and occipital headache aggravated by extension of the neck and turning of the head to the right. His pre operative three positional study (Fig. 3) showed multiple unco vertebral spurs indenting the vertebral arteries. Narrowing of the right vertebral artery at C 5—6 was notably accentuated by turning to the right and diminished on turning to the left. On the latter maneuver, the left internal carotid buckled. The neck was somewhat flexed this time.

A second angiography (Fig. 4) 8 months following anterior fusion at C 5—6 showed marked diminution in the displacement of the right vertebral artery at this level and no compression *of this artery on turning to the right. On turning to the left, with the head more extended this* time, no buckling of the left carotid artery occurred. The patient considered himself cured.

Case 4 (vertebral artery compression and occlusion) R. G., a 47 year old white male entered hospital complaining of positionally induced dizziness and faintness. His pre operative angiography (Fig. 5) revealed mild compression of the vertebral arteries by unco-vertebral spurs at C 5—6 and mild displacement of the right vertebral artery by spurs at C 4—5. On turning to the left, the notably smaller left artery was occluded by the C5—6 spurs and the compression of the right vertebral artery disappeared. The displacement at the C 4—5 on the right was unchanged. On turning to the right there was slight compression of the right vertebral artery at C 4—5 and marked compression at C 5—6.

Six months following anterior fusion at C 5—6, a repeat angiography (Fig. 6) showed considerable diminution of the spurs. There was no compression of the vertebral artery on turning to the right or the left.

Conclusions

There is no single angiographic approach to the study of cerebrovascular disease which answers all of our needs, but in our opinion, transfemoral three positional pancervical angiography is *the single, simplest, best tolerated* and most informative initial study. It does not obviate the need for precise intra cranial angiography by selective catheterization (15) or direct puncture of an appropriate carotid or vertebral artery. There remains a considerable discrepancy between angiographically demonstrable lesions and symptomatically important lesions. While buckling has not been found to be of great significance in *our experience, notable relief of* vertebral artery compression by spurs subsequent to anterior cervical fusion has been well documented by pre and post operative three positional studies.

SUMMARY

Experiences with transfemoral three positional pancervical angiography are reviewed This in our opinion is the simplest best tolerated and most informative initial examination but it does not necessarily obviate the need for precise intra-cranial angiography Buckling of the carotid artery is of lesser significance than vertebral artery compression by osteophytic spurs Relief of the latter has in two of our patients been accomplished by anterior cervical fusion

ZUSAMMENFASSUNG

Unsere Erfahrung mit der drei positionalen pancervicalen Angiographie wird erlautert Diese stellt die einfachste am besten vertragliche und informative Untersuchung dar ohne dass sie eine genau durchgefuhrte intrakranielle Angiographie uberflussig macht Deformierungen der A carotis sind von geringerer Bedeutung als die Kompression der A vertebralis durch Osteophyten Letztere konnten bei zwei unserer Patienten durch eine anteriore cervicale Fusion beseitigt werden

RÉSUMÉ

Les auteurs tirent les conclusions de leur expérience de l angiographie pancervicale à trois positions par voie fémorale C est l examen initial le plus simple le mieux toléré et le plus instructif mais elle ne dispense pas toujours d une angiographie intracranienne précise Les tortuosités de la carotide ont moins d importance qu la compression de l artère vertébrale par des becs ostéophytiques Le traitement de cette compression a été fait chez deux des malades des auteurs par fusion cervicale antérieure

REFERENCES

1 AMPLATZ J RESCH J and HILAL S A catheter approach for cerebral angiography Radiology 81 (1963) 576

2 BANNISTER D G and MURRAY LESLIE R M Veno-angiography in cerebrovascular disease Brain 86 (1963) 161

3 BAUER R B SHEEHAN S WECHSLER N and MEYER J S Arteriographic study of sites incidence and treatment of arteriosclerotic cerebrovascular lesions Neurology 12 (1962) 698

4 FARIS A A POSER C M WILMORE D W and AGNEW C H Radiologic visualization of neck vessels in healthy men Neurology 13 (1963) 386

5 GURDJIAN E S HARDY W G LINDNER D W and THOMAS L H Four vessel angiography Experiences with three hundred consecutive cases Clin Neurosurg 10 (1964) 251

6 — LINDNER D W HARDY W G and THOMAS L H Incidence of surgically treatable lesions in cases studied angiographically Neurology 11 (1961) 150

7 HANAFEE W Axillary artery approach to carotid vertebral abdominal aorta and coronary angiography Radiology 81 (1963) 559

8 KOVACS A Subluxation and deformation of the cervical apophyseal joints Acta radiol 43 (1955) 1

Case 1 (normal) L K a 58 year old Indian male with rheumatic heart disease was investigated for possible occlusive cerebrovascular disease His three positional pancervical angiogram (Fig 1) was essentially normal The origins of the vessels the carotid bifurcations and the entirety of the surgically accessible cerebral arterial supply were demonstrated The neutral right and left rotation series provided multiple views avoided overlap and elucidated any effect of position change on arterial lumen size Serial filming occasionally obviates over lap also especially of the vertebral artery origin

Case 2 (occlusive disease) G C a 66 year old white male with symptoms of cerebrovascular insufficiency showed stenosis of the left internal and external carotid arteries (Fig 2) The multiple views aided in delineating the extent of the process and obviated overlapping

Case 3 (vertebral artery compression and carotid buckling) S W a 42 year old colored male had complaints of dizziness and occipital headache aggravated by extension of the neck and turning of the head to the right His pre operative three positional study (Fig 3) showed multiple unco vertebral spurs indenting the vertebral arteries Narrowing of the right vertebral artery at C 5—6 was notably accentuated by turning to the right and diminished on turning to the left On the latter maneuver the left internal carotid buckled The neck was somewhat flexed this time

A second angiography (Fig 4) 8 months following anterior fusion at C 5—6 showed marked diminution in the displacement of the right vertebral artery at this level and no compression of this artery on turning to the right On turning to the left with the head more extended this time no buckling of the left carotid artery occurred The patient considered himself cured

Case 4 (vertebral artery compression and occlusion) R G a 47 year old white male entered hospital complaining of positionally induced dizziness and faintness His pre operative angiography (Fig 5) revealed mild compression of the vertebral arteries by unco-vertebral spurs at C 5—6 and mild displacement of the right vertebral artery by spurs at C 4—5 On turning to the left the notably smaller left artery was occluded by the C5—6 spurs and the compression of the right vertebral artery disappeared The displacement at the C 4—5 on the right was unchanged On turning to the right there was slight compression of the right vertebral artery at C 4—5 and marked compression at C 5—6

Six months following anterior fusion at C 5—6 a repeat angiography (Fig 6) showed considerable diminution of the spurs There was no compression of the vertebral artery on turning to the right or the left

Conclusions

There is no single angiographic approach to the study of cerebrovascular disease which answers all of our needs, but in our opinion, transfemoral three positional pancervical angiography is the single, simplest, best tolerated and most informative initial study It does not obviate the need for precise intra cranial angiography by selective catheterization (15) or direct puncture of an appropriate carotid or vertebral artery There remains a considerable discrepancy between angiographically demonstrable lesions and symptomatically important lesions While buckling has not been found to be of great significance in our experience, notable relief of vertebral artery compression by spurs subsequent to anterior cervical fusion has been well documented by pre and post operative three positional studies

FROM THE UNIVERSITY DEPARTMENT OF NEURORADIOLOGY, RIGSHOSPITALET
COPENHAGEN, DENMARK

ARTERIOVENOUS FISTULA AFTER PERCUTANEOUS VERTEBRAL ANGIOGRAPHY

by

JACK LESTER

More than a hundred arteriovenous fistulas on the vertebral arteries most of them after penetrating injuries have previously been described (ELKIN & HARRIS 1946) but ARONSON (1961) was the first to demonstrate these fistulas arteriographically

Although SUGAR et coll as early as 1949 mentioned the possibility of an arteriovenous fistula as a complication of percutaneous vertebral angiography these fistulas are apparently uncommon as only a few cases have been described in the literature since OLSON et coll in 1963 published the first

The three additional cases of this complication reported here suggest that it is perhaps not as rare as has been presumed As they are to be included in a future paper (JACOBSEN et coll) which also describes two fistulas after closed injuries they will only be summarized here

Case reports

Case 1 Male aged 21 with a subarachnoid haemorrhage without focal neurologic symptoms or signs Bilateral carotid angiography and percutaneous left vertebral angiography under taken by a less experienced operator revealed nothing abnormal After this last examination the patient was troubled by tinnitus and he was re admitted 7 months later for further investigation This revealed a machinery murmur over the middle of the left side of the neck and

9 MARSHALL T R and LING J T Direct percutaneous non catheter left and right brachial angiography Radiology 80 (1963) 258
10 NEWTON T H The axillary artery approach to arteriography of the aorta and its branches Am J Roentgenol 89 (1963) 275
11 POSER C M SNODGRASS R C and FARIS A A Radiologic visualization of neck vessels in cerebrovascular insufficiency J Amer med Ass 182 (1962) 126
12 SHEEHAN S, BAUER R B and MEYER J S Vertebral artery compression in cervical spondylosis Neurology 10 (1960) 968
13 SHENKIN H A TATSUMI T and BENTLEY D Simplified method for total cerebral angiography J Amer med Ass 182 (1962) 132
14 STEIN B M McCORMICK W F RODRIGUEZ J N and TAVERAS J M Radiography of atheromatous disease involving the extracranial arteries as seen at post mortem Acta radiol 1 (1963) 455
15 WESCOTT S L CHIANG K Y and STEINBERG I Percutaneous transfemoral selective arteriography of the brachiocephalic vessels Am J Roentgenol 90 (1963) 554
16 WHALEN R E HEYMAN A and McINTOSH H D Cinefluoroscopy of extracranial cerebral circulation Circulation 28 (1963) 503

FROM THE UNIVERSITY DEPARTMENT OF NEURORADIOLOGY RIGSHOSPITALET, COPENHAGEN, DENMARK

ARTERIOVENOUS FISTULA AFTER PERCUTANEOUS VERTEBRAL ANGIOGRAPHY

by

JACK LESTER

More than a hundred arteriovenous fistulas on the vertebral arteries most of them after penetrating injuries have previously been described (ELKIN & HARRIS 1946) but ARONSON (1961) was the first to demonstrate these fistulas arteriographically

Although SUGAR et coll as early as 1949 mentioned the possibility of an arteriovenous fistula as a complication of percutaneous vertebral angiography these fistulas are apparently uncommon as only a few cases have been described in the literature since OLSON et coll in 1963 published the first

The three additional cases of this complication reported here suggest that it is perhaps not as rare as has been presumed As they are to be included in a future paper (JACOBSEN et coll) which also describes two fistulas after closed injuries they will only be summarized here

Case reports

Case 1 Male aged 21 with a subarachnoid haemorrhage without focal neurologic symptoms or signs Bilateral carotid angiography and percutaneous left vertebral angiography under taken by a less experienced operator revealed nothing abnormal After this last examination the patient was troubled by tinnitus and he was re admitted 7 months later for further investigation. This revealed a machinery murmur over the middle of the left side of the neck and



Transfemoral catheterization demonstrates arterio venous fistula on the left vertebral artery 6 months after percutaneous vertebral angiography

an arteriovenous fistula of the left vertebral artery was demonstrated by transfemoral catheterization (see accompanying illustration)

Case 2 Boy aged 14 with attacks of rotatory vertigo tinnitus and headache The left plantar response was extensor but no other abnormal neurologic signs were found On suspicion of a vascular malformation left vertebral angiography was done by a less experienced operator The angiography revealed nothing abnormal After this the tinnitus changed from a humming noise it turned into a rhythmic blowing sound The remaining symptoms were unchanged The patient was re admitted six months later and a machinery murmur was auscultated over the left side of the neck Transfemoral angiography revealed an arteriovenous fistula on the left vertebral artery similar to the one found in case 1

Case 3 Woman aged 26 with a six months history of rotatory vertigo and headache For two weeks she had had buzzing in both ears She was admitted to another hospital and on suspicion of a space occupying infratentorial lesion left sided percutaneous vertebral angiography was attempted The examination was unsuccessful as the needle could not be held in position in the artery Sixteen ml Urografin 60 % was injected but no intracranial filling was obtained After this the tinnitus increased and a rhythmic blowing sound which had not been present before the examination could be heard on the left side of the neck The patient was transferred to our hospital and 16 days later a transfemoral catheterization revealed an arteriovenous fistula on the left vertebral artery similar to the fistulas seen in cases 1 and 2

Discussion

The angiographic technique used was that described by LINDGREN (1950), but a Sheldon needle with a small side aperture 2 to 3 mm from the trocar pointed tip as modified by SWANN (1958), was used instead of the ordinary short bevel needle After the introduction of the Swann needle we considered that puncture of the vertebral artery was so simple that every neuroradiologist experienced in carotid angiography should be able to perform vertebral angiography However on analysis of 337 examinations carried out over a period of 5 years (LESTER & KLEE) we found 8 local complications including 6 cases of brachial plexus irritation and 2 arteriovenous fistulas (cases 1 and 2) In all these 8 cases the angiography had been carried out by less experienced investigators under supervision whereas the really experienced operators who performed 45 % of all examinations had caused no local complications It was also found that in 6 of 8 cases with local complications including the 2 cases of arteriovenous fistula the investigator had had technical difficulties Consequently, we have now made it a rule that only experienced, qualified neuroradiologists carry out percutaneous vertebral angiography

Arteriovenous fistulas are also seen after diagnostic puncture of other arteries for instance the two arteries most frequently used for indirect vertebral angiography the brachial (SAMUEL 1962) and the femoral (MCAFEE 1957) The risk of producing a fistula of the vertebral artery is probably greater however as with that artery the puncture hole cannot be closed by digital compression

Although an arteriovenous fistula on the vertebral artery may be a serious complication we still consider percutaneous vertebral angiography performed by a skilled and experienced operator to be a rapid and satisfactory examination

SUMMARY

Three cases of arteriovenous fistula on the vertebral artery have been demonstrated by transfemoral catheterization All of them developed after a previous percutaneous vertebral angiography performed by a less experienced operator under technical difficulties Consequently only skilled experienced investigators should carry out these examinations

ZUSAMMENFASSUNG

Mittels transfemoraler Katheterisierung wurden drei Falle von arteriovenosen Fisteln der Vertebralarterie gezeigt Alle Falle entwickelten sich im Anschluss an eine fruhere perkutane Vertebralisangiographie die von einem weniger erfahrenen Untersucher unter technischen Schwierigkeiten vorgenommen worden war Es ergibt sich daraus dass nur geschickte erfahrene Untersucher diese Angiographie durchfuhren sollten

RÉSUMÉ

Trois cas de fistule artério-veineuse de l'artère vertébrale ont été mis en évidence par cathétérisme transfémorale. Tous sont apparus après une angiographie vertébrale percutanée faite par un opérateur moins expérimenté, au milieu de difficultés techniques. Il faudrait donc que ces examens ne soient faits que par des opérateurs adroits et expérimentés.

REFERENCES

ARONSON, N. I.: Traumatic arteriovenous fistula of the vertebral vessels. Neurology 11 (1961) 817.

ELKIN, D. C. and HARRIS, M. H.: Arteriovenous aneurysm of the vertebral vessels. Ann. Surg. 124 (1946) 934.

JACOBSEN, B., KLEE, A. and LESTER, J.: Arteriovenous aneurysm of the vertebral vessels. To be published.

LESTER, J. and KLEE, A.: *Complications of 337 percutaneous vertebral angiographies.* Acta neurol. scand. 41 (1965) 301.

LINDGREN, E.: Percutaneous angiography of the vertebral artery. Acta radiol. 33 (1950) 389.

— Another method of vertebral angiography. Acta radiol. 46 (1956) 257.

McAFEE, J. G.: A survey of complications of abdominal aortography. Radiology 68 (1957) 825.

OLSON, R. W., BAKER, H. L. and SVIEN, H. J.: *Arteriovenous fistula: a complication of vertebral angiography.* J. Neurosurg. 20 (1963) 73.

SAMUEL, E.: Percutaneous brachial catheterization. Brit. J. Radiol. 35 (1962) 468.

SUGAR, O., HOLDEN, L. B. and POWELL, C. B.: Vertebral angiography. Amer. J. Roentgenol. 61 (1949) 166.

SWANN, G. F.: Vertebral angiography using the Sheldon needle and modification of it. Brit. J. Radiol. 31 (1958) 23.

FROM THE NEUROROADIOLOGY SECTION OF THE DEPARTMENT OF RADIOLOGY AND THE DEPARTMENT OF NEUROLOGY, NEW YORK UNIVERSITY MEDICAL CENTER NEW YORK, U S A

MICROANGIOGRAPHIC CHANGES IN THE TRAUMATIZED BRAIN

by

J PEN TZE LIN N E CHASE I I KRICHEFF, F ALEU M GOLDBAUM and W K HASS

The increased use of motorized transportation has caused a sharp rise in the incidence of acute head trauma The treatment of serious acute head trauma is often unrewarding and the reasons for poor response to treatment in many instances are not well understood (BENDER 1960 CLARKE & ROWBOTHAM 1963 HUNTER 1960) The purpose of this investigation was to determine if any changes might be demonstrated in the microscopic vessels in the traumatized brain by microangiographic techniques Human autopsy material was used initially but because of lack of control over the time interval between death and autopsy and an incomplete knowledge of the exact nature and amplitude of the injuring force it was decided to concentrate our work on laboratory animals which could be studied under optimal controlled conditions

Material and methods

Albino male rats weighing 300 gm were traumatized with a specially con

RÉSUMÉ

Trois cas de fistule artério-veineuse de l'artère vertébrale ont été mis en évidence par cathétérisme transfémorale. Tous sont apparus après une angiographie vertébrale percutanée faite par un opérateur moins expérimenté au milieu de difficultés techniques. Il faudrait donc que ces examens ne soient faits que par des opérateurs adroits et expérimentés.

REFERENCES

ARONSON N. I. Traumatic arteriovenous fistula of the vertebral vessels. Neurology 11 (1961) 817.

ELKIN D. C. and HARRIS M. H. Arteriovenous aneurysm of the vertebral vessels. Ann Surg 124 (1946) 934.

JACOBSEN B., KIFF A. and LESTER J. Arteriovenous aneurysm of the vertebral vessels. To be published.

LESTER J. and KIFF A. Complications of 337 percutaneous vertebral angiographies. Acta neurol scand 41 (1965) 301.

LINDGREN E. Percutaneous angiography of the vertebral artery. Acta radiol 33 (1950) 389.

— Another method of vertebral angiography. Acta radiol 46 (1956) 257.

MCAFEE J. G. A survey of complications of abdominal aortography. Radiology 68 (1957) 825.

OLSON R. W., BAKER H. L. and SVIEN H. J. Arteriovenous fistula: a complication of vertebral angiography. J Neurosurg 20 (1963) 73.

SAMUEL E. Percutaneous brachial catheterization. Brit J Radiol 35 (1962) 468.

SUGAR O., HOLDEN L. B. and POWELL C. B. Vertebral angiography. Amer J Roentgenol 61 (1949) 166.

SWANN G. F. *Vertebral angiography using the Sheldon needle and modification of it.* Brit J Radiol 31 (1958) 23.



Fig 1 Normal microangiogram *Top view* Orderly parallel perforating vessels perpendicular to brain surface with a size of about 80 micra 100 × *Lower view* Good demonstration of capillary beds 200

(1963) and by PEREZ et coll (1964) with a size of about 80 micra There was good demonstration of the capillary bed (Fig 1) The microangiogram of the immediate post trauma group demonstrated marked diminution in the caliber of the perforating vessels to a size of less than 20 micra There was also reduction in the capillary networks (Fig 2) The one day post trauma microangiogram showed a return toward normal in the caliber of the vessels but an increased tortuosity of those vessels There was further diminution in the filling of the capillaries (Fig 3) A gradual return to normal appearance could be seen on the microangiograms on succeeding days The caliber of the perforating vessels had almost returned to normal in the five days post trauma group and the filling of the capillary bed was only moderately decreased (Fig 4)

The most significant histologic feature was the presence of an edematous

platform and immobilized. The rat was brought to the third stage of anesthesia with ether and as the rat began to come out of anesthesia, a brass ball was dropped from a height of 90 cm. In this way, a sudden momentum of 2.9×10^4 dyne seconds (momentum ft $= mv$, $v = \sqrt{2gh}$) was applied to the vertex *of the rat's skull*. Twenty one rats were divided into seven groups. One non traumatized group was used as a control. The other six groups were traumatized on the same day. Microangiography was performed immediately post trauma on the first group. The other groups were studied, one group for each succeeding day for five days. Prior to microangiography, the rats were anesthetized with 15 mg of Nembutal intraperitoneally. The abdominal cavity was opened and the abdominal aorta and inferior vena cava were separated. A 19 gauge blunt cannula was introduced into the abdominal aorta and the inferior vena cava was sectioned. Heparinized dextrose solution was injected into the aorta until there was a clear return from the inferior vena cava. Then a 75% microbarium suspension in a 2% gelatin solution was injected into the aorta at a constant pressure of 300 mm Hg by gravity for 20 to 30 minutes (colloid barium sulfate, particle size range from 0.1 to 0.3 micra, Bell Craig, Inc., New York). The rats were refrigerated but not frozen for 2 hours before removing the brain. The brain was fixed in a 10% buffered formalin solution for 3 days. 0.5 mm and 1.0 mm frozen sections were obtained for radiograms. The radiograms were obtained on Kodak high resolution plates using a Beryllium window x-ray tube with the exposure factors of 16 kV, 40 mA and *20 minutes exposure time at a distance of 100 cm. The plates were viewed* with a microscope and photomicrographs were obtained at 25 power and 50 power magnifications. Frozen and paraffin sections were also taken for histologic examination.

Results

Clinically the typical reaction immediately post trauma was that the rats would curl up and stop breathing for about 20 seconds, the respiration gradually returned to normal over a period of about 5 minutes. By then they were completely awake, though not too active. Gross examination of the intracranial contents of the immediate and one day post trauma groups revealed obvious subdural and subarachnoid blood. The amount of subdural and subarachnoid blood decreased rapidly with time so that none could be observed on the third, fourth and fifth post trauma days.

The normal microangiogram demonstrated orderly, parallel perforating vessels perpendicular to the brain surface as described by ZEMAN & INNES



Fig 3 Microangogram of one day post trauma group *Top view* A return toward normal in caliber of perforating vessels but increased tortuosity of these vessels 100 × *Lower view* A further diminution in filling of capillaries 200 ×

Discussion

The temporary respiratory depression of the rats immediately after the strike was also observed by DENNY BROWN & RUSSELL (1941) They attributed it to the stimulation of the vago glossopharyngeal system by the subthreshold blows *In this study* the severe narrowing of the perforating vessels as seen in the immediate *post trauma* group also might be sufficient to cause transient anemia of the brain and lead to temporary respiratory depression

FLOREY in 1925 found that the cerebral vessels of cats reacted to mechanical thermal electrical and chemical stimuli by *contraction* and he could not demonstrate the evidence of any nervous control over the caliber of the *cerebral* vessels ECHLIN (1942) also demonstrated constriction of individual pial blood vessels following mechanical and *electrical* stimuli, and the constriction was not dependent on neurovascular mechanism DENNY BROWN & RUSSELL did

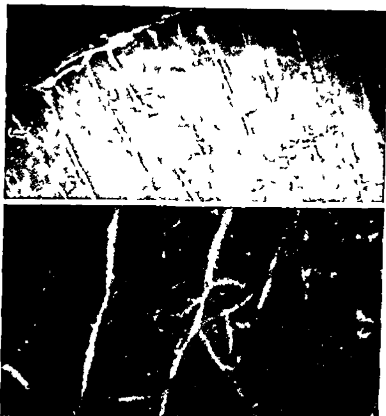


Fig 2 Microangiogram of immediate post trauma group *Top view* Marked diminution in caliber of perforating vessels to a size of less than 20 micra 100 × *Lower view* Reduction in filling of capillary networks compared with fig 1 lower view 200

reaction which became more apparent one day after the traumatic injury The edema was noted in cortex and white matter It should be noted that rats have very little white matter and therefore fluid accumulation was more significant within the cortex In our animals the cortical glial cells (astrocytes) exhibited marked swelling and vacuolization (Fig 5) Clear vacuoles were also noted within the white matter The edema was much less apparent in the animals studied immediately and five days after the traumatic injury (Fig 6) It should be emphasized that in these experiments inflammatory changes associated with cellular infiltrates did not occur Evidence of neuronal degenerative changes was not found A number of medium sized vascular structures appeared to have very prominent clear perivascular zones which seemed to be more prominent in the animals sacrificed immediately after trauma (Fig 7)



Fig 3 Microangiogram of one day post trauma group *Top view* A return toward normal in caliber of perforating vessels but increased tortuosity of these vessels 100 × *Lower view* A further diminution in filling of capillaries 200 ×

Discussion

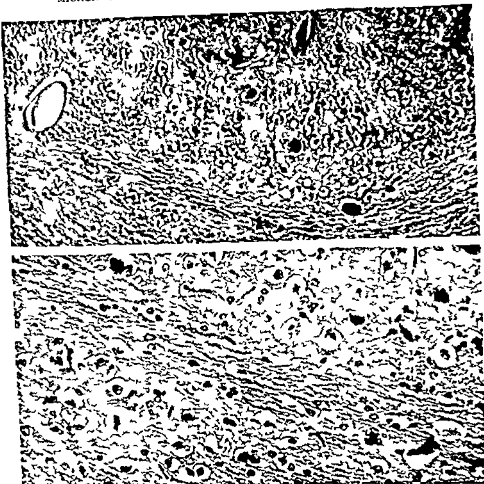
The temporary respiratory depression of the rats immediately after the strike was also observed by Denny Brown & Russell (1941) They attributed it to the stimulation of the vago glossopharyngeal system by the subthreshold blows In this study the severe narrowing of the perforating vessels as seen in the immediate post trauma group also might be sufficient to cause transient anemia of the brain and lead to temporary respiratory depression

Florey in 1925 found that the cerebral vessels of cats reacted to mechanical thermal electrical and chemical stimuli by contraction and he could not demonstrate the evidence of any nervous control over the caliber of the cerebral vessels Echlin (1942) also demonstrated constriction of individual pial blood vessels following mechanical and electrical stimuli and the constriction was not dependent on neurovascular mechanism Denny Brown & Russell did



Fig. 4. Microangiogram of five days post trauma group. *Top view:* Almost normal appearance of perforating vessels compared with fig. 1 top view. 100 ×. *Lower view:* Moderately decreased capillary networks compared with fig. 1 lower view. 200 ×.

not find evidence of cerebral vasospasm by direct stimulation of the vasomotor center in the medulla of dogs. Our explanation for the marked vascular narrowing as seen in the immediate post trauma group was that it was the result of mechanical stimulation and the presence of subarachnoid blood. The sudden strike on the vertex of the rat's skull induced a sudden movement of the brain within the cranial cavity which acted as a direct mechanical stimulation to the cerebral vessels and resulted in vascular narrowing. The presence of subarachnoid blood might also play a role in the development of vascular narrowing. Individual and topographic differences accounted for a wide range in the size of the vessels as noted on histologic sections. This precluded a meaningful evaluation of the presence or absence of vascular spasm. Equally dangerous would be to draw inferences from the appearance of the clear perivascular zone. The prominence of this region could be enhanced



F g 5 H tolog c sect on of one day post trauma group *Top iew* Marked swelling and vacuolizat on of cortic l glial cells (ast ocytes) and clear vacuoles within the wh te matter 100 × *Lower view* 400

by marked reduction of the vessel size swelling of the perivascular astrocytic foot processes and shrinkage and sectioning artifacts There was no evidence of neuronal damage in our specimens as was seen in the studies of GROAT et coll (1945) EVANS (1945) and WINDLE et coll (1944)

In the one and two days post trauma group the cortical vessels were tortuous as seen in the microangiograms and there was evidence of cerebral swelling in the corresponding histologic sections These findings were consistent with the findings seen in experimental cerebral edema by PEREZ et coll





Fig 6 (Above) Histologic section of five days post trauma group showed that the edema was much less apparent 100

Fig 7 (Below) Histologic section of immediate post trauma group showed very prominent clear perivascular zones 100 ×

i e , the tortuosity of the vessels was due to their compression by the expanding swollen brain tissues

Rockoff & Ommaya s (1964) experiment demonstrated consistent cerebral circulatory slowing following head trauma in monkeys, They attributed this to arterial spasm, cerebral edema and the development of intravascular aggre-

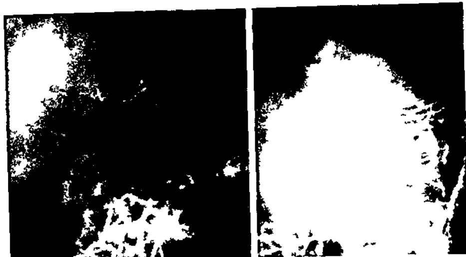


Fig 8 Carotid angiogram of a patient with temporal contusion demonstrated generalized spasm of anterior and middle cerebral arteries Middle cerebral artery was elevated and displaced medially There was no evidence of subdural hematoma

gations of blood cells The present study demonstrated that vascular narrowing occurred prior to the development of cerebral edema and may be due to unrelated factors

It has been our experience and the experience of others (COLUMELLA et coll 1963 FREIDENFELT & SUNDSTROM 1963 and GREITZ & LINDGREN 1961) to see localized or generalized areas of vascular narrowing in angiograms of patients with severe head trauma (Fig 8) It now seems probable from this work that there is also extensive narrowing of the microvasculature in the patients with severe head trauma This generalized vascular narrowing may in part be responsible for the cerebral signs accompanying head trauma and may explain the frequent lack of response to treatment It also is important to stress the fact that the vascular narrowing occurred prior to the development of cerebral edema This adds supporting evidence to the concept of independent and separate mechanisms for the establishment of vascular spasm and that of cerebral edema

Acknowledgements

This work was supported in part by the New York City Health Research Council Contract No U 1175 Dr Joseph P Lin is a post residency trainee in neuroradiology Program is supported in part by the National Institutes of Health (National Institute for Neurological Diseases and Blindness) Contract No 5433 01





Fig 6 (Above) Histologic section of five days post trauma group showed that the edema was much less apparent 100 ×

Fig 7 (Below) Histologic section of immediate post trauma group showed very prominent clear perivascular zones 100

i e , the tortuosity of the vessels was due to their compression by the expanding swollen brain tissues

Rockoff & Ommaya s (1964) experiment demonstrated consistent cerebral circulatory slowing following head trauma in monkeys, They attributed this to arterial spasm, cerebral edema and the development of intravascular aggre-

HUNTER A R Basic considerations in the conservation care of head injuries Postgrad med J 36 (1960) 370
PEREZ C A HODGES III F I and MARGULIS A R Microangiography in experimental cerebral edema in rats Radiology 82 (1964) 529
ROCKOFF S D and OMMAYA A K Experimental head trauma cerebral angiographic observations in the early post traumatic period Amer J Roentgenol 91 (1964) 1026
WINDLE W F GROAT R A and FOX C A Experimental structural alterations in the brain during and after concussion Surg Gynec Obstet 79 (1944) 561
ZEMAN W and INNES J R M Craigie s neuroanatomy of the rat Academic Press New York and London 1963

SUMMARY

Microangiographic findings after experimental head traumas in animals are described The immediate post trauma group demonstrated marked diminution in the caliber of the perforating vessels which occurred *prior to the development of cerebral edema* *The microangiographic* findings were correlated with histologic findings The possible mechanisms for the vascular spasm are discussed

ZUSAMMENFASSUNG

Es werden mikroangiographische Befunde nach experimentellen Schadelverletzungen an Tieren beschrieben Die posttraumatische Gruppe zeigte unmittelbar nach den Trauma eine markante Verminderung des Kalibers der perforierenden Gefässe noch bevor sich ein zerebrales Ödem entwickelte Die mikroangiographischen werden mit den histologischen Befunden korreliert Die moglichen Mechanismen die zum Auftreten von Gefasspasmen fuhren werden besprochen

RÉSUMÉ

Description des lésions microangiographiques cérébrales après traumatismes craniens expérimentaux chez des animaux On constate dans le groupe d animaux étudié immédiatement apres le traumatisme une réduction marquée du calibre des vaisseaux perforants qui apparait avant l oedème cérébral Les signes microangiographiques sont confrontés avec les signes histologiques L auteur examine les mécanismes possibles du spasme vasculaire

REFERENCES

BENDER M B Recovery from subdural hematoma without surgery Mt Sinai Hosp J (N Y) 27 (1960) 52

CLARKE P R R and ROWBOTHAM G F The management of head injuries Postgrad med J 39 (1963) 709

COLUMELLA F DELZANNO G B GAIST G and PIAZZA G Angiography in traumatic cerebral lacerations with special regard to some less common aspects Acta radiol 1 (1963) 239

DENNY BROWN D and RUSSELL W R Experimental cerebral concussion Brain 64 (1941) 93

ECHLIN F A Vasospasm and focal cerebral ischemia (An experimental study) Arch Neurol Psychiat (Chicago) 47 (1942) 77

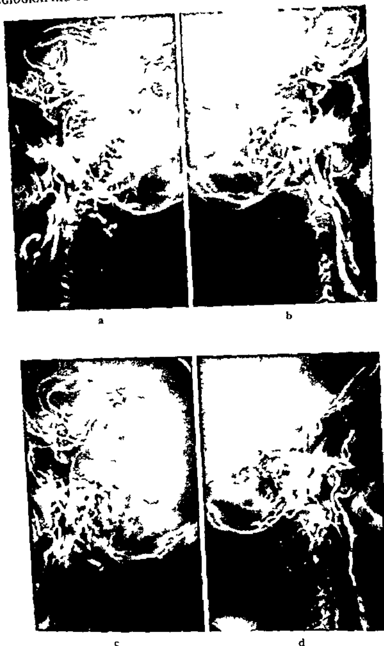
EVANS J P Histologic studies of the brain following head trauma J Neurosurg 2 (1945) 306

FLOREY H Microscopical observation on the circulation of the blood in the cerebral cortex Brain 48 (1925) 43

FREIDENFELT H and SUNDSTROM R Local and general spasm in the internal carotid system following trauma Acta radiol 1 (1963) 278

GREITZ T and LINDGREN E *Intracranial traumatic changes Angiography (Edited by* Abrams H L) Vol 1 Chap 7 P 95 Little Brown & Co Boston Mass 1961

GROAT R A WINDLE W F and MAGOWN H W Functional and structural changes in the monkey s brain during and after concussion J Neurosurg 2 (1945) 26



a b

c d

Fig 1 a) and b) B lat al carotid ang ogram showing marked athe omatous h nges in both ca otid systems No compl c tions rose c) and d) Repeat exam nat on 9 months late Occlus on f both internal ca otid arteries Hem pa esi occurred mmed ately afte this study

FROM THE DEPARTMENT OF NEUROSURGERY, WAYNE STATE UNIVERSITY SCHOOL OF MEDICINE, AND THE GRACE DETROIT MEMORIAL HOSPITALS, DETROIT, MICHIGAN, U S A

COMPLICATIONS OF ANGIOGRAPHY IN PATIENTS WITH VASCULAR AND ANAPLASTIC AND OTHER DISEASE OF THE NERVOUS SYSTEM

by

D W LINDNER and E S GURDJIAN

Cerebral angiography has acquired sudden and widespread acceptance and use in this country in the past ten years At the present time it is mandatory for the proper evaluation of certain vascular disorders affecting the central nervous system

Any classification of complications of angiography must of necessity be a rather complex one, since each of the various mechanisms must be considered in the light of on the one hand the many conditions for which angiography is performed and on the other hand the wide range in the ages and physical conditions of the patients being examined A simple classification to be used in this paper utilizes four categories (1) chemical, (2) mechanical, (3) infectious, and (4) complications arising from the condition of the patient and the disease process Obviously, there is some overlapping and the exact placement of each and every complication into one of the above headings may be impossible, but such a consideration is valuable for discussion

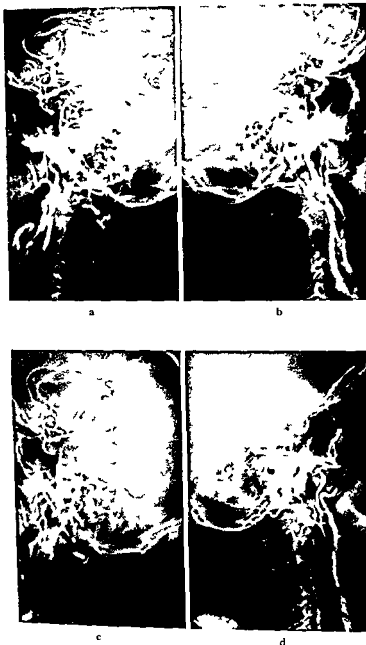


Fig 1 a) and b) B l t ral carot d angiogram showing marked atheromatous changes n b th carot d systems No compl cations arose) and d) Repeat examination 9 months later O clus on of both internal carotid arteries Hem p res s occurred mmediately after thi study

FROM THE DEPARTMENT OF NEUROSURGERY, WAYNE STATE UNIVERSITY SCHOOL OF MEDICINE, AND THE GRACE DETROIT MEMORIAL HOSPITALS, DETROIT, MICHIGAN, USA

COMPLICATIONS OF ANGIOGRAPHY IN PATIENTS WITH VASCULAR AND ANAPLASTIC AND OTHER DISEASE OF THE NERVOUS SYSTEM

by

D W LINDNER and E S GURDJIAN

Cerebral angiography has acquired sudden and widespread acceptance and use in this country in the past ten years At the present time it is mandatory for the proper evaluation of certain vascular disorders affecting the central nervous system

Any classification of complications of angiography must of necessity be a rather complex one, since each of the various mechanisms must be considered in the light of on the one hand the many conditions for which angiography is performed and on the other hand the wide range in the ages and physical conditions of the patients being examined A simple classification to be used in this paper utilizes four categories (1) chemical, (2) mechanical, (3) infectious, and (4) complications arising from the condition of the patient and the disease process Obviously, there is some overlapping and the exact placement of each and every complication into one of the above headings may be impossible, but such a consideration is valuable for discussion

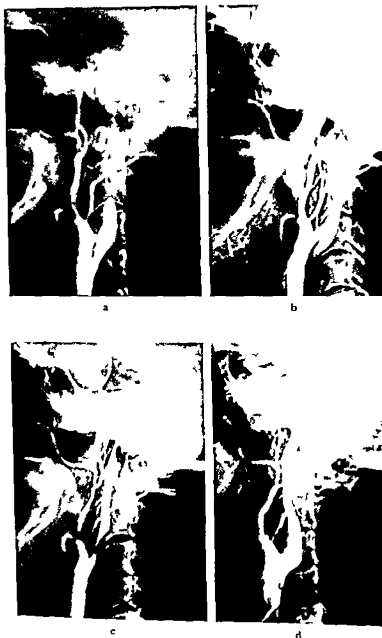


Fig 3 a) Subintimal injection b) Repeat injection after readjustment of needle in lumen of vessel c) Repeat injection several hours after (a) and (b) Contralateral hemiparesis had developed d) Postendarterectomy (Hemiparesis cleared after endarterectomy)

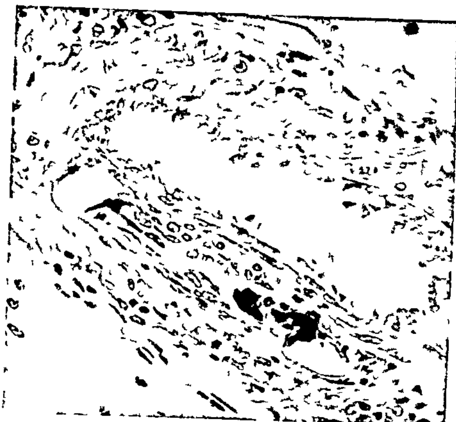


Fig. 2. Asymptomatic cotton fiber embolus following carotid angiography

Causes of complications

Chemical effects. The intrinsic toxicity of the contrast material may itself cause complications. It is universally accepted that Diodrast is toxic to the cerebral vessels. Prior to our use of sodium diatrizoate (Hypaque) we performed a number of animal experiments in an attempt to determine the relative specific toxicity to the cerebral vessels of Diodrast, Hypaque, Renografin, Urokon, and Thorotrast (LINDNER et coll. 1958). In brief, the results of these experiments revealed that Diodrast and Urokon were extremely toxic, this being measured by the technique described by BROMAN & OLSSON (1948). Thorotrast in this particular respect was by far the least toxic of all, although it has delayed effects.

The effects of rapid injection of Hypaque into the carotid artery of a dog were usually fourfold: (1) transient apnea followed by temporary increase in respiration, (2) temporary slowing of the pulse, (3) temporary dilatation of the pupil on the side of the injection, and (4) occasional movements of the facial musculature. These effects were present to greater or lesser extent with the other contrast media (except Thorotrast). The more toxic materials



Fig 4 a) Subintimal injection Needle was withdrawn and pressure applied over puncture site b) Repeat injection 3 days later

vessel (Fig 3) When this is observed on the initial film it is wise to withdraw the needle immediately and observe the patient closely for any developing neurologic deficits Infrequently subintimal injection can result in vessel occlusion and severe neurologic deficit However in a majority of cases simple compression at the site of injection for a period of minutes may result in absorption of the contrast material and re establishment of normal flow within the artery (Fig 4)

A delayed effect of interstitial injection with weakening of the arterial wall may result in aneurysm formation (Fig 5) The initial angiographic study with an interstitial injection at the point of the needle is seen to the left Within three weeks an aneurysmal dilatation developed directly at the site of the interstitial injection

There are other mechanical effects unrelated to actual injections but directly related to manipulation by the point of a needle We are somewhat surprised that more cases of jugular carotid fistulae have not been reported

caused seizures immediately after injection in some animals. Using the technique described by BROMAN & OLSSON, two types of changes were noted. In some animals, there was a 'regional' effect, consisting of staining of the brain in the area bathed by the vessel injected. In other animals, there were punctate hemorrhages, usually in the region of the basal ganglia. These latter changes were frequently noted in brains not showing the regional effect, and were bilateral from unilateral injection.

Like many other workers, we found that sodium diatrizoate was the least toxic of the materials studied.

As regards other aspects of the chemical effects of contrast media, their toxicity is no doubt enhanced by certain conditions in the patient. Both hypo and hypertensive changes produced during the angiographic procedure, and in part due to the condition of the patient, *may result in complications.* There is general agreement that the concentration of the contrast medium in the blood is significant in reducing complications (Fig. 1).

Mechanical factors. Mechanical factors in the production of angiographic complications have become more and more apparent. Since the angiography is now done so that the site of injection and the needle is included on the film, interstitial or subintimal injections, or an injection into the tissues of the neck, may be seen on the exposed film. Similarly when the needle is inserted directly through or into an atheromatous plaque, the course taken by the needle may be observed on the film. In one case the needle was inserted directly into the region of an atheromatous plaque in the neck. Immediately after injection this patient complained of inability to see toward the side of the injection. Clinically she had a homonymous field defect, and funduscopically occlusion of one of the main branches of the ophthalmic artery was observed. This visual field defect persisted in the form of a quadrantic defect and it was felt that the embolus represented a so called 'hard' or cholesterol embolus in contrast to a 'soft' or fibrin embolus which may well dissolve in a period of time.

Another complication arising directly from needle puncture is thrombosis with propagation. There is no question that in cases of atheromatous carotid stenosis any manipulation in the region of involvement can cause clot formation and propagation of thrombus. Another form of embolization is that of cotton fiber embolus (Fig. 2). These emboli obviously result from improper handling and cleaning of needles during the procedure and for the most part should be avoidable.

The improper placement of a needle in the carotid in the neck can result in intramural injection of contrast material with subsequent occlusion of the



F g 4) Sub nt mal injection. Needle was withd awn and pressure applied over puncture site b) Repeat i jection 3 days late

vessel (Fig 3) When this is observed on the initial film it is wise to withdraw the needle immediately and observe the patient closely for any developing neurologic deficits Infrequently subintimal injection can result in vessel occlusion and severe neurologic deficit However in a majority of cases simple compression at the site of injection for a period of minutes may result in absorption of the contrast material and re establishment of normal flow within the artery (Fig 4)

A delayed effect of interstitial injection with weakening of the arterial wall may result in aneurysm formation (Fig 5) The initial angiographic study with an interstitial injection at the point of the needle is seen to the left Within three weeks an aneurysmal dilatation developed directly at the site of the interstitial injection

There are other mechanical effects unrelated to actual injections but directly related to manipulation by the point of a needle We are somewhat surprised that more cases of jugular carotid fistulae have not been reported



a b

Fig. 5 a) Intramural injection b) Aneurysmal dilatation 3 weeks after (a)

following carotid angiography, since the introduction of the needle into both the jugular vein and the carotid artery is not an uncommon occurrence. We have had instances of Horner's syndrome following carotid angiography. This may either be due to the injection of local anesthetic into the sympathetic chain or it may result from direct trauma to the sympathetic chain from needle manipulation. Pneumothorax has occurred in both carotid and subclavian angiography. Local hematoma at the site of needle injection is a fairly common occurrence in both carotid and brachial angiography. Hematoma of surgical significance, however, is in our experience unusual. We have had one example of a patient who required tracheotomy following carotid angiography because of hematoma with tracheal compression and deviation and one example of massive cervical hematoma with dissection into the mediastinum resulting in death. We have examples of transient loss of radial pulse following retrograde brachial angiography, and have been told of one instance of occlusion of a brachial artery due to hemorrhage with subsequent infection, gangrene, and loss of the extremity.

Complications in patients with spontaneous subarachnoid hemorrhage from ruptured intracranial aneurysms are difficult to interpret. One is frequently asked whether the pressure of injection might not result in the re-

rupture of an aneurysm and subsequent bleeding We have had only one example of contrast material extruding from a ruptured intracranial aneurysm during the angiographic procedure This patient was almost moribund at the time of examination the angiogram was obtained because of the possibility of a subdural or epidural hematoma

Infection Infectious causes for angiographic complications, in our experience have not occurred We feel very fortunate in this regard and like to feel that it is due to good surgical techniques both in the preparation and handling of instruments used and in the rather meticulous surgical scrubbing prior to angiography In our area we have seen one example of osteomyelitis of the cervical spine occurring after carotid angiography We have also seen four cases of cervical abscess following carotid angiography all of which resulted in the loss of the entire carotid complex on the side of infection

Disease process and condition of patient

This category is perhaps the most difficult of all to interpret with respect to complications There is agreement that the poor condition of the patient may be a contraindication to the employment of angiography However the disease process in a given case may help cause complications not ordinarily expected in a patient in relatively good condition In two previous communications (LATIMER et coll 1952 LINDNER et coll 1962) we have stated that in the presence of angiographically demonstrable atheromatous changes in the vessels the complication rate for angiography is relatively higher In an attempt to verify this stand we have reviewed several series of cases specifically with this in mind One series of cases was selected only because both the carotid and vertebral arteries were examined on both sides (GURDJIAN et coll 1963) In 300 consecutive cases complications were not d in 14 instances Hemiparesis occurred following carotid angiography in 2 cases Both of these cases had contralateral carotid stenosis of 50 % or greater noted on the angiogram Another case of hemiparesis occurred following brachial angiography and in this instance generalized atheromatous changes were noted in both carotid and vertebral systems Death occurred in one case in this series and angiography revealed complete middle cerebral occlusion The patient at autopsy was found to have severe rheumatic heart disease and pulmonary edema Cardiac fibrillation occurred following carotid angiography in one case examined for a possible subdural hematoma Cervical hematoma of significant size was noted in another case in which carotid and vertebral atheromatous changes were seen on the films Significant hypotension occurred in six instances

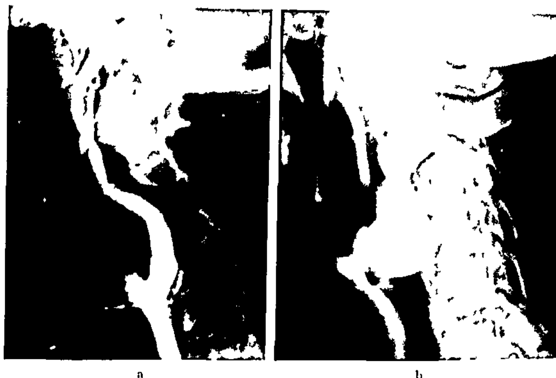


Fig. 5. (a) Intramural injection. (b) Aneurysmal dilatation 3 weeks after (a).

following carotid angiography, since the introduction of the needle into both the jugular vein and the carotid artery is not an uncommon occurrence. We have had instances of Horner's syndrome following carotid angiography. This may either be due to the injection of local anesthetic into the sympathetic chain or it may result from direct trauma to the sympathetic chain from needle manipulation. Pneumothorax has occurred in both carotid and subclavian angiography. Local hematoma at the site of needle injection is a fairly common occurrence in both carotid and brachial angiography. Hematoma of surgical significance, however, is in our experience unusual. We have had one example of a patient who required tracheotomy following carotid angiography because of hematoma with tracheal compression and deviation and one example of massive cervical hematoma with dissection into the mediastinum resulting in death. We have examples of transient loss of radial pulse following retrograde brachial angiography, and have been told of one instance of occlusion of a brachial artery due to hemorrhage with subsequent infection, gangrene, and loss of the extremity.

Complications in patients with spontaneous subarachnoid hemorrhage from ruptured intracranial aneurysms are difficult to interpret. One is frequently asked whether the pressure of injection might not result in the re

studies In this series any death occurring within twenty four hours of an angiographic study was considered a possible angiographic complication

On review of the total cases 8 of the 13 were felt to be directly related to angiography Of these eight patients cerebrovascular disease was a major diagnosis in five Of the remaining three cases one had a cardiac arrest during induction of anesthesia one was found to have a primary tumor of the pulmonary artery and the third had generalized carcinomatosis with cerebral metastases

In this same series of 1 000 cases the non fatal complications numbering eleven included 8 cases with major diagnosis of cerebrovascular disease In the remaining three one patient had an episode of coronary spasm when all of the contrast material at the time of carotid angiography went retrograde a second case developed heart block during operative exposure of the brachial arteries and a third case experienced radicular pain following percutaneous left cervical vertebral angiography

SUMMARY

Complications from cerebral angiography result from a number of interrelated mechanisms these include the chemical effects of contrast media the mechanical factors involved in manipulation of the vessels and needle insertion infectious causes and the existence of various disease processes in the patients which in one way or another contribute to some or all of the mechanisms mentioned above The most significant disease process in the production of most of the serious complications of angiography is the presence of cerebrovascular disease in particular atheromatous changes in the major vessels

ZUSAMMENFASSUNG

Komplikationen bei cerebraler Angiographie kommen durch eine Anzahl untereinander verwandter Mechanismen zustande Diese umfassen die chemischen Wirkungen von Kontrastmittel die mechanischen Faktoren wie Manipulation mit den Gefässen und Einfuhrung der Injektionsnadel Ursachen von Infektionen und Vorhandensein verschiedener krankhafter Zustande der Patienten die auf die eine oder andere Art be einigen oder allen oben genannten Mechanismen mitwirken Die wichtigste Erkrankung im Zusammenhang mit den ernsten Komplikationen bei der Angiographie ist das Vorhandensein einer cerebrovaskularen Erkrankung insbesonders atheromatose Veranderungen in den grosseren Gefässen

RÉSUMÉ

Les complications de l angiographie cérébrale résultent de plusieurs mécanismes interdépendants ils comprennent les effets chimiques des moyens de contraste les facteurs mécaniques liés à la manipulation des vaisseaux et à l introduction de l aiguille les causes infectieuses et l existence chez les malades de divers processus morbides qui d une façon

The angiographic findings in the 1 000 patients with cerebrovascular disease were as follows

Internal carotid stenosis	204
Bilateral 97	
Internal carotid occlusion	91
Bilateral 10	
Anterior cerebral artery occlusion	118
Middle cerebral artery occlusion	38
Vertebral basilar occlusion	102
Aneurysm/arteriovenous malformation	37
Intracerebral hematoma (surgical)	23
Subdural hematoma	12
Brain tumor	50

In all of the patients, evidence of moderate to severe atheromatous changes was noted at angiography. All of the fourteen cases in this series having complications were in the sixth decade or later in life and all the cases having complications had a final diagnosis of some form of cerebrovascular disease. Five complications occurred associated with the use of general anesthesia, the remainder occurred during the use of local anesthesia.

Considering the disease categories in a series of 300 cases it was noted that 67 had demonstrable vascular disease in the carotid system, 26 in the vertebral basilar system, 81 were considered 'small artery disease', and 22 were being examined for possible aneurysm or arteriovenous malformation. The remaining 104 patients were brain tumor suspects or patients with vague non focal complaints, including convulsive disorders.

The overall morbidity of 4.4 % and mortality of 0.3 % may be compared with a second series of complications occurring in a group of 1 000 consecutive patients studied for cerebrovascular disease (LINDNER et coll. 1962).

The angiographic complications in this series are summarized below.

Deaths	
Occlusive cerebrovascular disease	6
Aneurysm/arteriovenous malformation	2
Tumor of pulmonary artery	1
Metastatic carcinoma to brain	1
Hemorrhage or hemorrhagic infarction	2
Cardiac arrest	1
Transient weakness	4
Persisting weakness	2
Embolus	1
Coronary spasm	1
Radiculitis	1
Heart block	1
Convulsion	1

In this series an overall morbidity and mortality of 2.4 % was counted with almost half of this figure representing possible mortalities from the

FROM THE DIVISIONS OF DIAGNOSTIC RADIOLOGY AND NEUROSURGERY UNIVERSITY OF WASHINGTON SCHOOL OF MEDICINE SEATTLE WASHINGTON U S A

APPLICATIONS OF ANGIOGRAPHY DURING INTRACRANIAL OPERATION

by

JOHN W LOOP and ELDON L FOLTZ

Cerebral angiography is usually a pre operative examination but post operative angiography also provides valuable information about the brain circulation and the condition of brain vessels (MOUNT & TAVERAS 1956 NORLIN 1949) There are no valid studies to indicate the best time for angio graphy after operation It has been the usual practice to delay it several weeks or months but we suggest that it might be more useful if the information gained by such an examination were available to the neurosurgeon immediately at operation This would allow revision or extension of the operation as indi cated by the angiogram Particularly dangerous or complicated vascular lesions could thus be assessed several times during operation so that operative accom plishment could be immediately balanced against the risk of additional surgical treatment

We have carried out cerebral angiography during operation for a variety of intracranial vascular diseases on ten patients to date There have been no special technical problems We have found it convenient to prepare and drape the neck separately from the cranium but to delay carotid puncture until immediately before contrast injection If several injections have been planned the carotid cannula is continuously irrigated Using a specially mounted manu

ou d une autre s associent à certains ou a tous les mécanismes mentionnés ci dessus Le processus morbide le plus important dans l apparition de la plupart des complications graves de l angiographie est la présence d une affection cérébro vasculaire, en particulier les lésions athéromateuses des gros vaisseaux

REFERENCES

BROMAN T and OLSSON O Tolerance of cerebrovascular vessels to contrast media Acta radiol 30 (1948) 326

LATIMER F R WEBSTER J E and GURDJIAN E S Complications of cerebral angiography Grace Hosp Bull July (1952) 1—4

LINDNER D W HARDY W G THOMAS L M and GURDJIAN E S Angiographic complications in patients with cerebrovascular disease J Neurosurg 14 (1962) 179

— CHASON J L MARTIN F A WEBSTER J E and GURDJIAN E S An evaluation of Hypaque Sodium (Win 8308 3) for cerebral angiography Surgery 43 (1958) 631

GURDJIAN E S HARDY W G LINDNER D W and THOMAS L M Four vessel angiography Experience with three hundred consecutive cases Clin Neurosurg 10 (1963) 251

FROM THE DIVISIONS OF DIAGNOSTIC RADIOLOGY AND NEUROSURGERY, UNIVERSITY OF WASHINGTON SCHOOL OF MEDICINE SEATTLE WASHINGTON U S A

APPLICATIONS OF ANGIOGRAPHY DURING INTRACRANIAL OPERATION

by

JOHN W LOOP and ELDON L FOLTZ

Cerebral angiography is usually a pre operative examination but post operative angiography also provides valuable information about the brain circulation and the condition of brain vessels (MOUNT & TAVERAS 1956 NORLIN 1949) There are no valid studies to indicate the best time for angio graphy after operation It has been the usual practice to delay it several weeks or months but we suggest that it might be more useful if the information gained by such an examination were available to the neurosurgeon immediately at operation This would allow revision or extension of the operation as indi cated by the angiogram Particularly dangerous or complicated vascular lesions could thus be assessed several times during operation so that operative accom plishment could be immediately balanced against the risk of additional surgical treatment

We have carried out cerebral angiography during operation for a variety of intracranial vascular diseases on ten patients to date There have been no special technical problems We have found it convenient to prepare and drape the neck separately from the cranium but to delay carotid puncture until immediately before contrast injection If several injections have been planned the carotid cannula is continuously irrigated Using a specially mounted manu

ou d une autre s associent à certains ou a tous les mécanismes mentionnés ci dessus Le processus morbide le plus important dans l apparition de la plupart des complications graves de l angiographie est la présence d une affection cérébro vasculaire en particulier les lésions athéromateuses des gros vaisseaux

REFERENCES

BROMAN T and OLSSON O Tolerance of cerebrovascular vessels to contrast media *Acta radiol* 30 (1948) 326

LATIMER F R WEBSTER J E and GURDJIAN E S Complications of cerebral angiography *Grace Hosp Bull July (1952) 1—4*

LINDNER D W HARDY W G THOMAS L M and GURDJIAN E S Angiographic complications in patients with cerebrovascular disease J Neurosurg 14 (1962) 179

— CHASON J L MARTIN F A WEBSTER J E and GURDJIAN E S An evaluation of Hypaque Sodium *(Win 8308 3) for cerebral angiography Surgery 43 (1958) 631*

GURDJIAN E S HARDY W G LINDNER D W and THOMAS L M Four vessel angiography Experience with three hundred consecutive cases Clin Neurosurg 10 (1963) 251

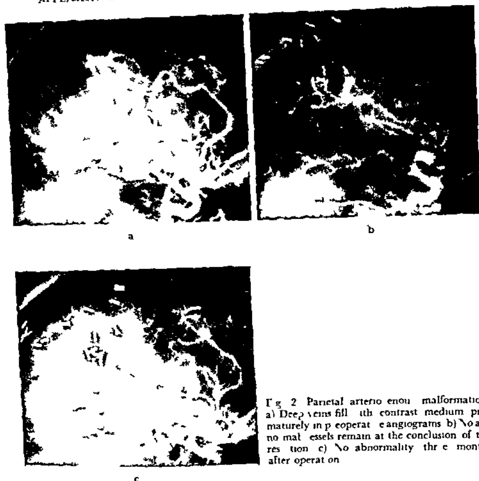


Fig 2 Parietal arterio enou malformation a) Deep veins fill ith contrast medium prematurely in p eoperat e angiograms b) No abno mal essels remain at the conclusion of the res tion c) No abnormality thr e months after operat on

Ca e 3 A 45 year old man had a twenty year history of increasing disability wi h left sided weakness and sensory loss A very large right parietal arteriovenous malformation was demonstrated on preoperative angiograms It could not be completely excised surgically although an attempt was made Most of the large feeding arteries were interrupted He improved temporarily but then developed right sided pulsating exophthalmos at which time angiograms showed striking enlargement of arteries which had formerly been small He has since been t eated by artificial embolization with opaque acrylic spheres introduced into the internal carotid artery as reported by LUESSENHOP et coll (1962) (Fig 3) It is desirable for obvious reasons that the number of artificial emboli be limited to tho e which are useful in occluding pathologic blood vessels A composite illustration in this case shows the vascularity after two aft r four and af er eight acrylic spheres have been introduced into the circulation Fig 4 The patient s proptosis is now gone His hemiparesis persists but he states he is abl to think more clearly and that he is more stable emotionally than preoperatively



Fig 1 Internal carotid artery aneurysm Angiogram during attempted ligation the neck of the aneurysm is not occluded

ally operated cassette changer (DI E I, G Schonander AB) under a sterile drape, we have been able to produce a series of three films We have also occasionally used Polaroid film for quick viewing

The following cases are presented to illustrate situations in which cerebral angiography during operation has been especially helpful to the neurosurgeon

Case reports

Case 1 A 60 year old woman had sudden headache right hemiplegia and aphasia Pre-operative angiography revealed a large aneurysm of the left internal carotid artery with several daughter protrusions It had a narrow neck on the angiogram and it was thought that this neck could be closed with a clip However at operation the neck of the aneurysm was thicker and stiffer than anticipated The surgeon tightened a silk ligature about it as much as he dared An angiogram was then made during operation and this showed the aneurysm filling as before (Fig 1) Having this information the surgeon immediately exercised his option to tie off the carotid artery in the neck The patient has had no further bleeding in a year since the initial episode and neurologic deficits were only transient

Case 2 A 21 year old man suddenly developed left hemiparesis His right carotid angiogram showed arteriovenous shunting from anterior middle and posterior cerebral arteries to the deep venous system (Fig 2a) His age good general condition and the location of his lesion were indications for surgical excision (POOLE 1962) It is desirable to do the most conservative operation which removes the lesion completely The angiogram assured the surgeon that he had left no malformed arteries deep to his resection (Fig 2b) No early venous filling was seen He therefore terminated the operation Three months later an angiogram showed an identical appearance (Fig 2c) The patient has had no clinical evidence of recurrence in a year



Fig 1 Internal carotid artery aneurysm Angiogram during attempted ligation the neck of the aneurysm is not occluded

ally operated cassette changer (DLI-1, G Schonander AB) under a sterile drape, we have been able to produce a series of three films We have also occasionally used Polaroid film for quick viewing

The following cases are presented to illustrate situations in which cerebral angiography during operation has been especially helpful to the neurosurgeon

Case reports

Case 1 A 60 year old woman had sudden headache right hemiplegia and aphasia Preoperative angiography revealed a large aneurysm of the left internal carotid artery with several daughter protrusions It had a narrow neck on the angiogram and it was thought that this neck could be closed with a clip However at operation the neck of the aneurysm was thicker and stiffer than anticipated The surgeon tightened a silk ligature about it as much as he dared An angiogram was then made during operation and this showed the aneurysm filling as before (Fig 1) Having this information the surgeon immediately exercised his option to tie off the carotid artery in the neck The patient has had no further bleeding in a year since the initial episode and neurologic deficits were only transient

Case 2 A 21 year old man suddenly developed left hemiparesis His right carotid angiogram showed arteriovenous shunting from anterior middle and posterior cerebral arteries to the deep venous system (Fig 2a) His age good general condition and the location of his lesion were indications for surgical excision (Poole 1962) It is desirable to do the most conservative operation which removes the lesion completely The angiogram assured the surgeon that he had left no malformed arteries deep to his resection (Fig 2b) No early venous filling was seen He therefore terminated the operation Three months later an angiogram showed an identical appearance (Fig 2c) The patient has had no clinical evidence of recurrence in a year

It is concluded that cerebral angiography during operation is useful in situations such as these The time required to carry out the injection and expose the films does not add significantly to the length of the operation No special complications have been encountered from angiography under these circumstances On the other hand in cases like those presented above the neurosurgeon has been furnished with information at a time when it was most useful in order to carry out a more precise and definitive operative procedure

SUMMARY

Three examples are presented in which cerebral angiography during operation provided information which was immediately helpful to the surgeon conducting the operation

ZUSAMMENFASSUNG

Es werden drei Beispiele gezeigt bei denen das Ergebnis einer cerebralen Angiographie die wahrend der Operation durchgefuhrt worden war von unmittelbarem Wert fur den operierenden Chirurgen war

RÉSUMÉ

Présentation de trois cas ou l angiographie cérébrale peropératoire a fourni des renseignements immédiatement utiles au chirurgien qui opérait

REFERENCES

LUESSENHOP A J GIBBS M and VELASQUEZ A C Cerebrovascular response to emboli Arch Neurol Psychiat 7 (1962) 264

MOUNT L A and TAVERAS J N Cerebral angiographic studies following surgical treatment of intracranial aneurysms Acta radiol 46 (1956) 333

NORLEN G Arteriovenous aneurysms of the brain Report of ten cases of total removal of the lesion J Neurosurg 6 (1949) 475

POOLE J L Treatment of arteriovenous malformations of the cerebral hemispheres J Neurosurg 19 (1962) 136



Fig 3 Arteriovenous malformation a) The vessels have enlarged following an earlier operation b) Acrylic spheroids occlude the major tributary arteries



Fig 4 Arteriovenous malformation Angiograms obtained during operation after two (left view) four (centre) and eight (right view) spheroids introduced into the internal carotid artery have embolized the lesion

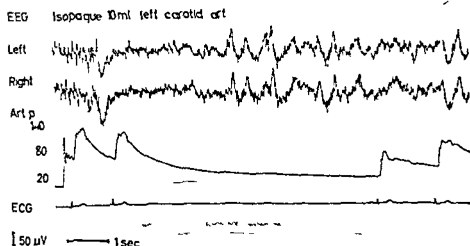


Fig 1 Carotid angiography with asystole for 6 sec and distinct fall of the blood pressure with bilateral electroencephalographic changes The upper two curves show electrical brain activity over left and right frontal parietal regions The third curve represents the intra arterial pressure in the common carotid artery The lower curve is the electrocardiographic record

In order to clarify both the circulatory effect and the brain wave changes in humans during cerebral angiography with different contrast media we have carried out the following investigations

Material and method

In the past 2 1/2 years polygraphic recordings have been taken during cerebral angiography in 300 patients In all 636 injections of contrast medium have been given in the carotid and vertebral arteries with the electroencephalogram electrocardiogram and the intra arterial blood pressure recorded simultaneously Injections of 8 to 20 ml contrast medium were given percutaneously into the common carotid artery into the vertebral artery or through a polyethylene catheter no 160 inserted into the same arteries Local anesthesia was used in most of the patients but general anesthesia was applied in special cases

The comparison was as a rule made between two different contrast media and saline as a control in each patient The sequence of injecting the two contrast solutions and a similar amount of saline was randomized to exclude the effect on the order of injections

Out of this material 19 patients were excluded either because of only one

FROM RIKSHOSPITALET, OSLO UNIVERSITY, NORWAY

POLYGRAPHIC RECORDINGS DURING CEREBRAL ANGIOGRAPHY

by

ARNE LUNDERVOLD and ARNE ENGESET

Cerebral angiography is not yet considered a completely innocent procedure and some complications both transient and permanent may occur. The contrast agents have therefore been tested in several ways. The effects on the EEG in both humans and laboratory animals were investigated by FOLTZ in 1952 and by THOMAS et coll. in 1954, who found either an immediate generalized flattening of electrical activity or homolateral production of new activity. INGVAR & SODERBERG (1957) examined both the EEG and the cerebral vasomotor tone.

GREITZ & WEISS (1959) *investigated the influence of Hypaque and Miokon* on the EEG and ECG in cerebral angiography. They found like INGVAR & SODERBERG, that the EEG was unchanged, but in the ECG rhythmical disturbances were recorded in some patients.

The circulatory effect in general of intracarotid injections of one particular or other contrast materials has been described by *several authors* (BROMAN & OLSSON 1948, HAUGE 1954, GREITZ 1956, LINDGREN & TORNELL 1958, FISHER & ECKSTEIN 1961 & 1962). On the other hand BULL & MURRAY LESLIE (1962) do not agree with all the findings in their animal studies and stress that one cannot place too much reliance on animal experiments alone.

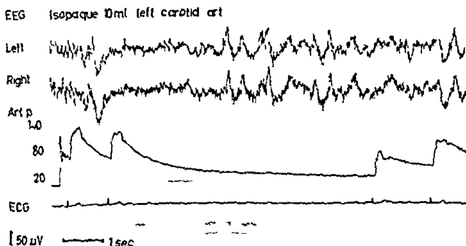


Fig 1 Carotid angiography with asystole for 6 sec and distinct fall of the blood pressure with bilateral electroencephalographic changes The upper two curves show electrical brain activity over left and right frontal parietal regions The third curve represents the intra arterial pressure in the common carotid artery The lower curve is the electrocardiographic record

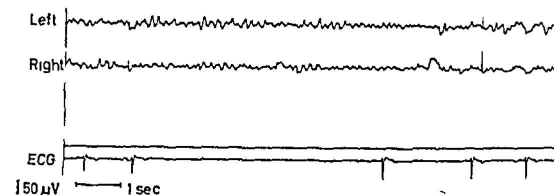
In order to clarify both the circulatory effect and the brain wave changes in humans during cerebral angiography with different contrast media we have carried out the following investigations

Material and method

In the past 2 1/2 years polygraphic recordings have been taken during cerebral angiography in 300 patients In all 636 injections of contrast medium have been given in the carotid and vertebral arteries with the electroencephalogram electrocardiogram and the intra arterial blood pressure recorded simultaneously Injections of 8 to 20 ml contrast medium were given percutaneously into the common carotid artery, into the vertebral artery or through a polyethylene catheter no 160 inserted into the same arteries Local anesthesia was used in most of the patients but general anesthesia was applied in special cases

The comparison was as a rule made between two different contrast media and saline as a control in each patient The sequence of injecting the two contrast solutions and a similar amount of saline was randomized to exclude the effect on the order of injections

Out of this material 19 patients were excluded either because of only one



a

Left
Right
ECG
Left
Right
ECG
50 µV 1 sec R S 44 years EEG nr 3136/64

b

Fig. 2. a) Vertebral angiography. The first injection of Isopaque 45 resulted in a 6 sec asystole. b) Second injection in same patient resulted in a 19 sec asystole.

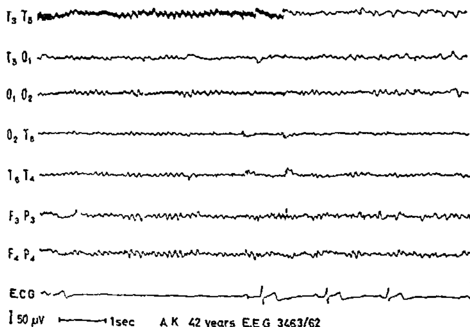


Fig 3 a Carotid angiography (Hypaque 10 ml) with asystole for 4 sec and simultaneous focal electroencephalographic changes with accompanying transient paresis of the extremities contralaterally The upper three curves and the sixth curve show the slow waves over the left hemisphere The other curves show normal activity over the right hemisphere

injection a defective filling or for other technical reasons The distribution of the remaining 281 patients was as follows

	Total	Female	Male	Right side	Left side
Carotid angiography	262	95	167	127	135
Vertebral angiography	19	8	11	8	11
Total	281	103	178	135	146

Results

The patients reacted generally very little to the injections as the EEG ECG and blood pressure remained unchanged

In some tense patients however we noted an increase in the blood pressure as well as an increased cardiac rate with a decrease of voltage in the EEG as often seen in arousal or in frightened patients All these responses or lack of responses were considered normal

A typical positive response consists of marked slowing of the heart rate

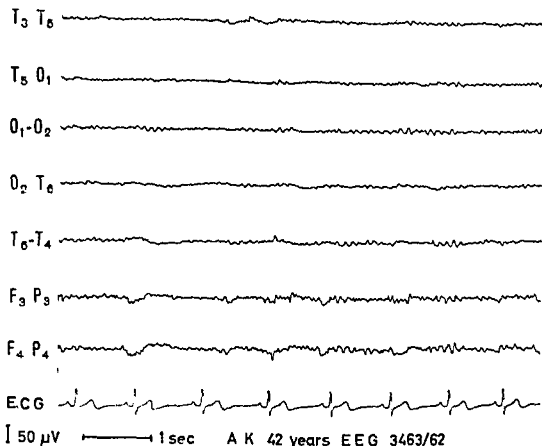


Fig 3b The following injection of saline in same patient gave no abnormal responses

and/or a brief period of asystole, starting 3 to 5 sec after the beginning of the injection (Fig 1)

In our tables only periods of asystole lasting more than 1 1/2 sec are shown because measuring slowing of the heart rate depends too much on the time over which the heart beats are counted Associated with asystole or slowing of the heart rate was a fall in the blood pressure, the magnitude of which correlates with the severity and duration of the drop in heart rate (Fig 1)

These responses do not appear to be caused by physical or chemical stimulation of the carotid sinus The effects on blood pressure and cardiac rate were present even when the carotid sinus was anesthetized, the catheter placed far beyond the sinus, or, most convincingly, when the contrast medium was injected into the vertebral artery, as shown in Fig 2 a

Even with a 15 minute period between the injections, the second injection gave, as a rule, more abnormal responses (Fig 2 b)

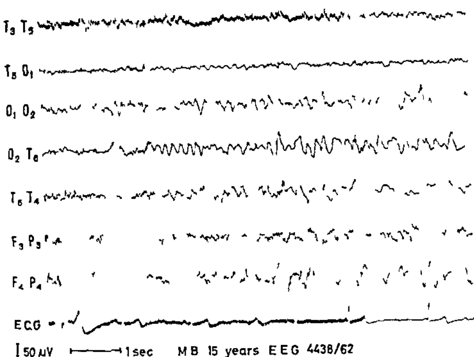


Fig 4 a Carotid angiography (Isopaque 10 ml) with focal electroencephalographic changes lasting 5 min with accompanying transient paralysis of the extremities contralaterally Abbreviation the same as in fig 3 a

The long lasting asystole caused drastic changes in the EEG as well

These abnormalities in the polygraphic recordings did not occur with injections of saline with compression of the carotid artery or palpation of the carotid sinus

We therefore believe that the slowing of the heart rate and the lowering of the blood pressure are caused by direct action of the contrast medium on the brain probably the hypothalamus the brain stem or other brain structures being supplied by the posterior cerebral artery as a much higher incidence of fall in blood pressure and slowing of the cardiac rate was noted when this artery was filled with contrast medium both in cerebral and vertebral angiography than when it was not seen (cf GREITZ) Other supporting evidence for this theory was found in the electroencephalographic findings

Fig 3a shows that in addition to the slowing (or asystole) of the heart rate a slowing of the brain waves also was recorded on the same side as

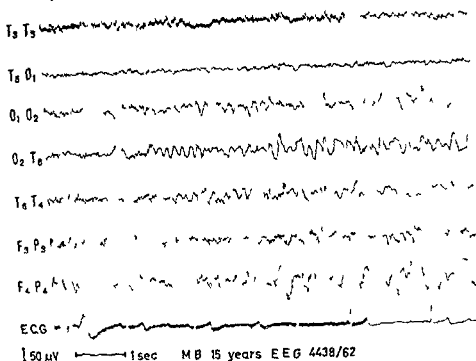


Fig 4 a Carotid angiography (Isopaque 10 ml) with focal electroencephalographic changes lasting 5 min with accompanying transient paralysis of the extremities contralaterally Abbreviation the same as in fig 3 a

The long lasting asystole caused drastic changes in the EEG as well

These abnormalities in the polygraphic recordings did not occur with injections of saline with compression of the carotid artery or palpation of the carotid sinus

We therefore believe that the slowing of the heart rate and the lowering of the blood pressure are caused by direct action of the contrast medium on the brain probably the *hypothalamus* the brain stem or other brain structures being supplied by the posterior cerebral artery as a much higher incidence of fall in blood pressure and slowing of the cardiac rate was noted when this artery was filled with contrast medium both in cerebral and vertebral angiography than when it was not seen (cf GREITZ) Other supporting evidence for this theory was found in the electroencephalographic findings

Fig 3a shows that in addition to the slowing (or asystole) of the heart rate a slowing of the brain waves also was recorded on the same side as

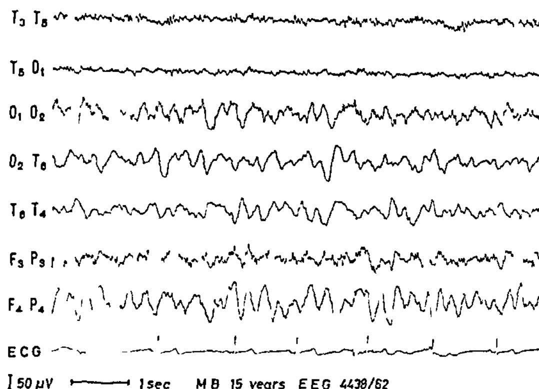


Fig 1b Curves obtained 10 sec later

that on which the injection was performed The following injection of the same amount of saline gave no abnormal responses (Fig 3b) If the abnormalities in the electroencephalograms lasted for several minutes they were followed by a contralateral hemiparesis and positive Babinski signs (Fig 4, a and b) *These clinical signs were transient, but we had two other patients* with probably permanent hemiparesis

In the first 106 patients, 10 ml Hypaque 45 % 10 ml Isopaque 45 %, and 10 ml saline were injected in different sequences (see below)

	Total	Female	Male	Right side	Left side
Percutaneously	37	13	24	23	14
Catheter method	69	22	47	31	38
Total	106	3[illegible]	71	54	[illegible]

There were no significant changes in the brain waves, heart rate or blood pressure responses (Table 1)

We observed however that there was a tendency for the contrast medium being injected through a polyethylene catheter to give more abnormal responses

Table 1

ECG and EEG abnormalities in 106 patients during 231 injections of contrast medium at cerebral angiography

	Asystole > 1 1/2 sec	Abnormal EEG	Total
Hypaque 45	17	18	35
Isopaque 45	16	20	36
Total	33	38	71

than the percutaneous injections Despite this the catheter method was used for the most part in the remaining group of patients primarily to prevent a dissecting aneurysm which sometimes happens with the percutaneous method Another reason is that the patients are much easier to handle during the roentgen procedure with a catheter rather than a needle in the carotid artery

In order to diminish or avoid these deleterious effects of the contrast medium of the brain a new more physiologic solution was composed in cooperation with the Norwegian firm Nyegaard & Co A/S and called Isopaque B It is based on the sodium salt of metrizoic acid and contains Ca and Mg in the same relative concentration as the human plasma

Animal experiments using rabbits and the same method as with the patients were first carried out In 26 rabbits of an average weight of 3 kg 2 ml Isopaque 45 % or 2 ml Isopaque B 45 % were injected in the carotid artery every third minute 6 injections in all or until the rabbit expired The injections were done under Urethan narcosis Table 2 shows the grade of complications

After these and other animal experiments had shown that the new medium Isopaque B was superior to the old one it was introduced into human angiography

In order to compare the two contrast media in human cerebral angiography both were injected every other time in alternate order interrupted by injec

Table 2

ECG and EEG abnormalities in 26 rabbits during 173 injections of contrast medium in the carotid artery

	ECG changes		EEG changes		
	Markedly abnormal	Moderately abnormal	Markedly abnormal	Moderately abnormal	Total
Isopaque 45	4	3	6	1	14
Isopaque B 45	0	3	2	4	9

Table 3

ECG and EEG abnormalities in 175 patients during 405 injections of contrast medium at cerebral angiography

	Asystole > 1 1/2 sec	Abnormal EEG
Isopaque 45 % only	19	16
Isopaque B 45 % only	3	7
Isopaque and Isopaque B	13	3
Total	35	26

tions of the same amount of saline In 175 patients, injections of Isopaque 45 % and Isopaque B 45 % were given as follows

	Right side	Left side	Total
Female	29	39	68
Male	52	55	107
Total	81	94	175

The results are shown in Table 3

The two sexes were compared as well as the two injection sides, but no significant changes were found Compression of the common carotid artery on one side gave no more positive responses

The age of the patients, the diagnosis, the premedication and the type of

Table 4

	Cerebral angiography Total	Complications with Hypaque 45 % and Isopaque 45 %	Complications with Isopaque B 45 %
Average age	37 1/2 years	45 years	50 1/2 years
Tumor intracranialis	31	46 %	56 %
Vascular lesions	26 %	14 %	11
Epilepsy	22 %	20	
Miscellaneous	21	20 %	33 %
Narcosis	24 %	17	6 %
Premedication			
Atropine	17	15	11 %
Morphine scopolamine	11 %	10 %	
Amycal			
Acid Isoamylaethylbarbituric	72 %	75	89

[1] Only one patient with asystole

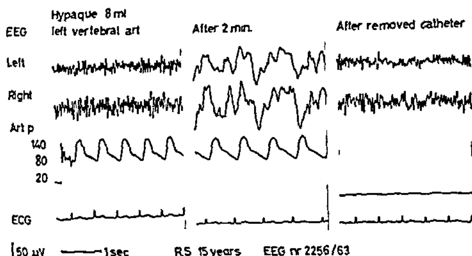


Fig 5 Left curve shows that injection of contrast medium through a catheter in the vertebral artery does not produce changes in electroencephalogram (upper two curves) intra arterial blood pressure or electrocardiogram Centre curve shows marked pathological activity in electroencephalogram recorded after catheter probably had obstructed vertebral artery for 2 min Right curve shows normal electroencephalogram taken immediately after withdrawal of catheter

anesthesia may influence the results Table 4 gives the number of patients in each of these groups classified after the polygraphic results

This table indicates also that Isopaque B is a better contrast medium than the ordinary type The average age is higher in the patients with complications and again highest in the group with complications after Isopaque B

In our material the anesthesia does not seem to have an unfavourable effect The same is the case with patients who have vascular lesions On the other hand we found more patients with tumors in the group with complications and especially with complication following injections of Isopaque B

We believed that the premedication was very important because other investigators (FISHER & PIRRET 1962) found in animal experiments that the vascular changes could be abolished by sectioning the vagus nerve In man, protection from the circulatory disturbances might be obtained with atropine blocking of the vagal responses (AMUNDSEN & AKSNES)

In our investigations atropine in general had a tendency to improve the results but it did not prevent all the complications especially not the EEG changes 6 of the 7 patients with complications had abnormal EEG recordings and only one patient had asystole for 1 1/2 seconds It is possible that even better results could be obtained with a more adequate dose of atropine

Table 3

ECG and EEG abnormalities in 175 patients during 405 injections of contrast medium at cerebral angiography

	Asystole > 1 1/2 sec	Abnormal EEG
Isopaque 45 % only	19	16
Isopaque B 45 % only	3	7
Isopaque and Isopaque B	13	3
Total	35	26

tions of the same amount of saline. In 175 patients, injections of Isopaque 45 % and Isopaque B 45 % were given as follows:

	Right side	Left side	Total
Female	29	39	68
Male	52	55	107
Total	81	94	175

The results are shown in Table 3.

The two sexes were compared as well as the two injection sides, but no significant changes were found. Compression of the common carotid artery on one side gave no more positive responses.

The age of the patients, the diagnosis, the premedication and the type of

Table 4

	Cerebral angiography Total	Complications with Hypaque 45 % and Isopaque 45 %	Complications with Isopaque B 45 %
Average age	37 1/2 years	45 years	50 1/2 years
Tumor intracranialis	31	46 %	56
Vascular lesions	26 %	14 %	11 %
Epilepsy	22 %	20	
Miscellaneous	21 %	20	33 %
Narcosis	21 %	17	6 %
Premedication			
Atropine[1]	17	15 %	11 %
Morphine scopolamine	11 %	10	
Amycal Acid Isoamylaethylbarbituric	72 %	75	89 %

[1] Only one patient with asystole.

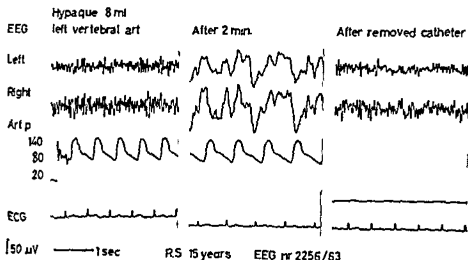


Fig 5 Left curve shows that injection of contrast medium through a catheter in the vertebral artery does not produce changes in electroencephalogram (upper two curves) intra arterial blood pressure or electrocardiogram Centre curve shows marked pathological activity in electroencephalogram recorded after catheter probably had obstructed vertebral artery for 2 min Right curve shows normal electroencephalogram taken immediately after withdrawal of catheter

anesthesia may influence the results Table 4 gives the number of patients in each of these groups classified after the polygraphic results

This table indicates also that Isopaque B is a better contrast medium than the ordinary type The average age is higher in the patients with complications and again highest in the group with complications after Isopaque B

In our material the anesthesia does not seem to have an unfavourable effect The same is the case with patients who have vascular lesions On the other hand we found more patients with tumors in the group with complications and especially with complications following injections of Isopaque B

We believed that the premedication was very important because other investigators (FISHER & PIRRET 1962) found in animal experiments that the vascular changes could be abolished by sectioning the vagus nerve In man protection from the circulatory disturbances might be obtained with atropine blocking of the vagal responses (AMUNDSEN & AASNES)

In our investigations atropine in general had a tendency to improve the results but it did not prevent all the complications especially not the EEG changes 6 of the 7 patients with complications had abnormal EEG recordings and only one patient had asystole for 1 1/2 seconds It is possible that even better results could be obtained with a more adequate dose of atropine

I 50 µV —— 1 sec

Fig 6 Seizure activity during general anesthesia with curare before angiography No clinical seizure signs visible after angiography when curare effect had disappeared

Even if the new contrast medium, Isopaque B, seems to be better than the previous one, it is not at all harmless to the brain Our radiological department has taken this into consideration and uses routinely polygraphic registration during angiography in all patients suspected of developing trouble or complications at the angiography Especially in view of the fact that the second or third injection seems to be more dangerous than the first, we believe that some patients have been spared transient or longer lasting brain damage, due to the warnings given by the polygraphic recordings

Not all the complications during angiography are caused by the contrast medium, however Fig 5 demonstrates that the obstruction produced by the catheter in the vertebral artery may cause very marked changes in the EEG, followed by unconsciousness In this case it was probably caused by a vessel anomaly as most, or all, of the blood supply to the basilar artery came from the obstructed vertebral artery

With patients having general anesthesia during angiography we have often used the polygraph throughout the whole procedure Fig 6 shows an electroencephalographically recorded seizure without clinical signs, as the patient was in general anesthesia, and curarized The EEG seizure started during the general anesthesia before the angiography, but first after the effect of the curare had disappeared were the clinical signs observed

Addendum in proofs

Since these investigations were completed some 200 more patients have been examined in the same way but the amount of contrast medium has been reduced from 10 to 7 ml The number of injections have also been minimized as much as possible

Presumably because of the reduced amount of a less toxic contrast medium the premedication with atropine and by reducing the intracranial pressure with Mannitol or Urea in patients with expanding lesions the changes in the polygraphic recordings have been reduced considerably

Among the first 100 patients about one third had changes in the ECG and about the same number had EEG disturbances

Because of the alteration in the roentgenological procedure mentioned above only 10 % of the last 100 patients had such changes and these were minimal compared with those among the first 100 patients

SUMMARY

Polygraphic recordings during cerebral angiography in 300 patients have shown marked changes in the electroencephalogram electrocardiogram and intra arterial blood pressure Electrocardiographic changes were found in 68 patients Focal slow waves in the electroencephalograms often combined with slight and more rarely with marked transient signs of hemiparesis were found in 64 patients when Hypaque 45 % and Isopaque 45 % was used as contrast medium The obstruction effect of the catheter could also produce slow waves in the EEG In a later similar study of 200 patients the polygraphic changes were reduced to about 10 % and were not as marked The cause was probably the reduction in the amount of contrast media from 10 to 7 ml the premedication with atropine and the reduction of the intracranial pressure in patients with expanding lesions

ZUSAMMENFASSUNG

An 300 Fallen wurden wahrend der cerebralen Angiographie polygraphische Aufzeichnungen vorgenommen die erhebliche Veranderungen im Electro-encephalogramm im Elektrocardiogramm und intra arteriellen Blutdruck aufzeigten Elektrocardiographische Veranderung wurden 68 mal gefunden Bei 64 Patienten zeigten sich nach Hypaque 45 % oder Isopaque 45 % örtliche verzogerte Wellen im E E G die ofter mit leichten Zeichen selten mit schwereren aber vorubergehenden Zeichen einer Hemiparese verknupft waren Der Obstruktionseffekt des Katheters konnte ebenfalls verlangsamte EEG Wellen hervorrufen Eine neue Serie von 200 Patienten zeigte die Nebenerscheinungen nur in 10 % der Falle und die Nebenerscheinungen waren milderer Natur Die Ursache war wahrscheinlich dass der Betrag des Kontrastmittels von 10 ml auf 7 ml reduziert wurde dass wir mit Atropin pramedikierten und den Hirndruck bei raumbeengenden Prozesse vorbeugend herabbrachten

RÉSUMÉ

Les enregistrements polygraphiques au cours de l angiographie cérebrale chez 300 sujets ont montré des altérations marquées de l électro-encephalogramme de l électrocardiogramme et de la pression intra artérielle On a trouvé des modifications électrocardiographiques chez 68 malades On a trouvé sur les électro-encéphalogrammes des ondes lentes focales souvent

associées à des signes légers et plus rarement marqués d'hémiparésie transitoire quand on utilise comme moyen de contraste l'Hypaque 45 % et l'Isopaque 45 %. L'obstruction par le cathéter peut aussi donner des ondes lentes sur l'EEG. Dans une étude similaire ultérieure sur 200 sujets, les altérations polygraphiques étaient réduites à environ 10 % et étaient moins marquées. La cause en est probablement la réduction de la quantité de moyen de contraste de 10 à 7 ml, la prémedication par l'atropine et la réduction de la pression intracranienne chez les malades atteints de tumeurs.

REFERENCES

AMUNDSEN, P. and AASNES, F.: Personal communication.

BROMAN, T. and OLSSON, O.: Tolerance of cerebral blood vessels to contrast medium of diodrast group; experimental study of effect on blood brain barrier. Acta radiol. 30 (1948): 376.

BULL, J. W. D. and MURRAY LESLIE, R. M.: Experience with metrizoate sodium (Isopaque) in cerebral angiography. A report on 33 cases. Farmacoterapi 1 (1962): 24.

FISCHER, H. W. and ECKSTEIN, J. W.: Comparison of cerebral angiographic contrast media by their circulatory effects. Amer. J. Roentgenol. 86 (1961): 166.

— — and PIRRET, G.: Comparison of the cardiovascular effects of contrast media in cerebral angiography in man. J. Neurosurg. 19 (1962): 943.

FOLTZ, E. L.: The EEG effects of intracarotid diodrast. Electroenceph. clin. Neurophysiol. 4 (1952): 113.

GREITZ, T. A.: Radiological study of brain circulation by rapid serial angiography of carotid artery. Acta radiol. Suppl. 140 (1956).

— and WEISS, S.: EEG and ECG in cerebral angiography with sodium diatrizoate (Hypaque) and methylglucamine diprotrizoate (Miokon). Acta radiol. 52 (1959): 145.

HAUGE, T.: Catheter vertebral angiography. Acta radiol. Suppl. 109 (1954).

INGVAR, D. H. and SODERBERG, U.: Cerebral vasomotor tone and EEG during injection of umbradil; experimental study with new method. Acta radiol. 47 (1957): 185.

LINDGREN, P. and TORNELL, G.: Blood circulation during and after peripheral arteriography. Acta radiol. 49 (1958): 425.

— — Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (triurol); experimental study in cats. Acta radiol. 50 (1958): 160.

LUNDERVOLD, A., SKRAASTAD, E. and BORGERSEN, A.: Cerebral angiography with simultaneous electroencephalographic, electrocardiographic and electromyographic recordings and measurement of intra-arterial pressure. Nord. Med. 70 (1963): 853.

THOMAS, L. B., FOLTZ, E. L. and WARD, JR., A. A.: The modification of cerebral electrical activity by intracarotid and topically applied diodrast. Electroenceph. clin. Neurophysiol. 6 (1954): 643.

FROM THE DIVISION OF NEUROSURGERY, DEPARTMENT OF SURGERY COLLEGE OF MEDICINE UNIVERSITY OF CINCINNATI U S A

ANGIOGRAPHIC OBSERVATIONS FOLLOWING REMOVAL OF SUBDURAL HEMATOMAS

by

ROBERT L McLAURIN and FREDRIC HELMER

The observations to be reported were made from serial angiographic studies on patients with subdural hematomas This is part of a larger project designed to investigate the usefulness of angiography following removal of benign expanding intracranial lesions Although pneumography has been used previously to follow the migration of intracranial structures there are limitations to the usefulness and value of that type of approach The purposes of the present study were 1) to delineate the normal anatomy as a base line against which comparison may be made in cases of suspected post operative recurrent hematomas and 2) to compare the appearance of the angiograms with clinical manifestations in order to understand neurologic changes occurring after hematoma removal

The material studied included angiograms on 19 patients Of these 18 had surgical evacuation of hematomas while 1 patient was followed through the period of complete spontaneous resolution of the hematoma In each case 1 preoperative angiogram was performed and 1 to 4 post-operative studies carried out

Return of the angiographic appearances to normal following evacuation of a subdural hematoma may be divided into two components 1) return of the

associés à des signes légers et plus rarement marqués d'hémiparésie transitoire quand on utilise comme moyen de contraste l'Hypaque 45 % et l'Isopaque 45 %. L'obstruction par le cathéter peut aussi donner des ondes lentes sur l'EEG. Dans une étude similaire ultérieure sur 200 sujets les altérations polygraphiques étaient réduites à environ 10 %, et étaient moins marquées. La cause en est probablement la réduction de la quantité de moyen de contraste de 10 à 7 ml, la prémédication par l'atropine et la réduction de la pression intracranienne chez les malades atteints de tumeurs.

REFERENCES

AMUNDSEN P and AKSNES F Personal communication

BROMAN T and OLSSON O Tolerance of cerebral blood vessels to contrast medium of diodrast group experimental study of effect on blood brain barrier Acta radiol 30 (1948) 326

BULL J W D and MURRAY LESLIE R M Experience with metrizoate sodium (Isopaque) in cerebral angiography A report on 33 cases Farmacoterapi 1 (196[illegible]) 24

FISCHER H W and ECKSTEIN J W Comparison of cerebral angiographic contrast media by their circulatory effects Amer J Roentgenol 86 (1961) 166

— — and PIRRET G Comparison of the cardiovascular effects of contrast media in cerebral angiography in man J Neurosurg 19 (1962) 913

FOLTZ E L The EEG effects of intracarotid diodrast Electroenceph clin Neurophysiol 4 (1952) 113

GREITZ T A Radiological study of brain circulation by rapid serial angiography of carotid artery Acta radiol Suppl 140 (1956)

— and WEISS S EEG and ECG in cerebral angiography with sodium diatrizoate (Hypaque) and methylglucamine diprotrizoate (Miokon) Acta radiol 52 (1959) 145

HAUGE T Catheter vertebral angiography Acta radiol Suppl 109 (1954)

INGVAR D H and SODERBERG U Cerebral vasomotor tone and EEG during injection of umbradil experimental study with new method Acta radiol 47 (1957) 185

LINDGREN P and TORNELL G Blood circulation during and after peripheral arteriography Acta radiol 49 (1958) 425

— — Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (triurol) experimental study in cats Acta radiol 50 (1958) 160

LUNDERVOLD A SKRAASTAD E and BORGERSEN A Cerebral angiography with simultaneous electroencephalographic electrocardiographic and electromyographic recordings and measurement of intra arterial pressure Nord Med 70 (1963) 853

THOMAS L B FOLTZ E L and WARD JR A A The modification of cerebral electrical activity by intracarotid and topically applied diodrast Electroenceph clin Neurophysiol 6 (1954) 643

FROM THE DIVISION OF NEUROSURGERY DEPARTMENT OF SURGERY COLLEGE OF MEDICINE UNIVERSITY OF CINCINNATI U S A

ANGIOGRAPHIC OBSERVATIONS FOLLOWING REMOVAL OF SUBDURAL HEMATOMAS

by

ROBERT L McLAURIN and FREDRIC HELMER

The observations to be reported were made from serial angiographic studies on patients with subdural hematomas This is part of a larger project designed to investigate the usefulness of angiography following removal of benign expanding intracranial lesions Although pneumography has been used previously to follow the migration of intracranial structures there are limitations to the usefulness and value of that type of approach The purposes of the present study were 1) to delineate the normal anatomy as a base line against which comparison may be made in cases of suspected post operative recurrent hematomas and 2) to compare the appearance of the angiograms with clinical manifestations in order to understand neurologic changes occurring after hematoma removal

The material studied included angiograms on 19 patients Of these, 18 had surgical evacuation of hematomas while 1 patient was followed through the period of complete spontaneous resolution of the hematoma In each case 1 preoperative angiogram was performed and 1 to 4 post operative studies carried out

Return of the angiographic appearances to normal following evacuation of a subdural hematoma may be divided into two components 1) return of the

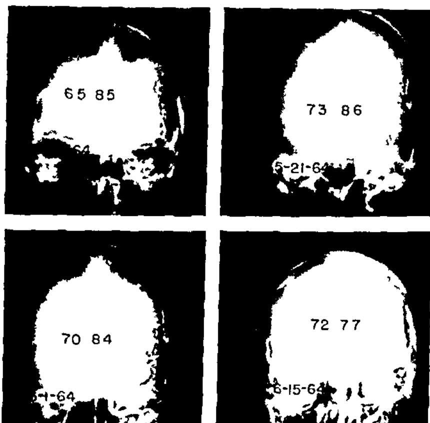


Fig 1 Case 1 Serial left carotid angiograms Slow recovery of midline position of anterior cerebral artery in spite of almost complete absence of subdural accumulation post operatively The numbers refer to measured distances of anterior cerebral artery from inner skull table Dates of studies are also shown Surgical drainage was performed on May 1, 1964

pericallosal artery to the midline, indicating recovery from shift of the vital midline structures, and 2) disappearance of the surface accumulation of fluid These aspects of arteriographic recovery may proceed independently, suggesting that shift of the midline vessels is not solely due to the surface hematoma In general, clinical recovery seemed to be related more closely to migration of the pericallosal artery to the midline position, although exceptions to this occurred in patients who made striking clinical recovery despite continued displacement of the midline structures

In 2 instances the pericallosal artery did not fill on the preoperative study and in 1 of these it was in midline position on the following day In all patients in whom displacement was demonstrated preoperatively the minimum time required for return to midline was 8 days and in most instances 2 to 4 weeks were required In 1 patient there was still a definite shift after 60 days and in this instance the clinical recovery progressed with reduction of the size of the



Fig 2 Case 2 Seri l right c ot d angiograms Absence of subdural accumulation 5 days post operatively and retu n of anterior cerebral artery to m dline at 2 weeks Surgical drainage was done on Oct 31 1963

surface hematoma and lateral migration of the sylvian point There was no indication that age modified the speed of post operative migration in any way

Four patients have been selected to illustrate several of the points observed in this study

Case reports

Case 1 C. R a 67 year-old male was admitted to the hospital on April 25 1964 following *an auto accident* On admission he was slightly confused but otherwise intact neurologically *During the* next few days a right hemiparesis and dysphasia appeared but later these seemed to subside Three weeks after admission the hemiparesis increased the conscious level *declined and a carotid* angiography demonstrated a left parieto-temporal hematoma The hematoma was immediately evacuated and thereafter he progressively and completely recovered Serial post-operative *angiograph es* were performed during the month following operation (Fig 1)

Six days following surgical intervention the sylvian point had returned to normal position and there was *only a small residual* accumulation despite continued marked displacement of the pericallosal artery It was still significantly displaced after 17 days and at 1 month had just returned to within *normal limits* The relatively slow return of the pericallosal artery in the presence of rapid *return of the sylvian point* is undoubtedly a reflection of the slow recession of edema of the cerebral substance

Case 2 N C a 62 year-old male was hospitalized on Oct 17 1963 following a fall of unknown cause On admission *he was deeply* comatose and had a left hemiplegia During the next few days he demonstrated a marked reco ery of function of the paretic extremities and 6 days after injury he was ambulatory *A diagnosis* of probable cerebrovascular occlusion disease was made and 2 weeks after admission carotid angiography was performed disclosing the presence of a large right subdural *accumulation* This was immediately evacuated and 2 post operative angiographies were done (Fig 2) Clinical recovery continued slowly during the 2 weeks following operation

Five days following surgical *intervention there* was no demonstrable surface accumulation although the pericallosal artery was still significantly displaced. Two weeks after *surgery the* vessel had returned to normal *position* The sylvian point originally displaced inward by approximately 2 cm returned to normal within 5 days Correlation of the clinical recovery

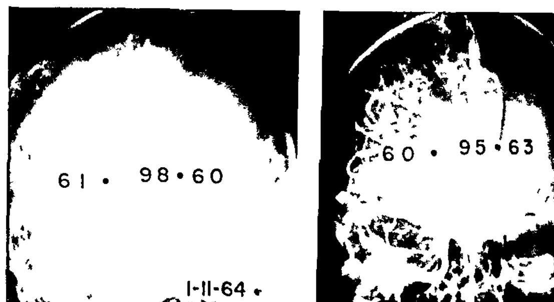


Fig 3 Case 3 Pre and post operative right carotid angiograms show only slight change of vascular displacement despite almost complete neurologic recovery The figures at left indicate distance of sylvian point from inner skull table Surgical drainage was done on Jan 11 1964

with the angiographic findings is hazardous since it seems quite probable in view of preoperative improvement that cerebral contusion was responsible for some of the deficit Nevertheless it appears that contusion and/or swelling of the hemisphere accounts for most of the neurologic disturbance rather than the surface pressure

Case 3 B O a 32 year old female a chronic alcoholic had fallen several times and complained of headache for about 7 days before admission to the hospital on Jan 11 1964 During the 2 days prior to admission she had gradually become less responsive On admission she was comatose had dilatation of the right pupil and right hemiparesis Carotid angiography demonstrated the presence of a large right subdural hematoma which was evacuated immediately On the following day she was markedly improved and awake with no motor weakness Five days after surgery a post operative angiography was carried out (Fig 3)

The significance of this case is the striking clinical recovery despite continued presence of marked shift of the pericallosal artery and inward displacement of the sylvian point It would appear that surgical intervention relieved the critical degree of intracranial displacement only It is possible that if she had never reached this critical displacement initially spontaneous recovery might have occurred At all events the observations in this case emphasize the lack of predictable relationship between intracranial vascular displacement and clinical manifestations

Case 4 H K a 60 year old male was admitted to the hospital on March 24 1964 because of confusion and disorientation associated with a history of chronic alcoholism Examination revealed aphasia and pathologic reflexes on the right Roentgenograms disclosed a pineal shift from left to right and carotid angiography showed a subdural hematoma Since the patient was demonstrating no neurologic deterioration it was decided to postpone surgical intervention During the ensuing 6 weeks 5 angiographies were done and there was gradual return of

vessels to the normal position with simultaneous disappearance of the subdural accumulation Clinically he made a progressive and complete recovery Following arteriographic recovery it was felt that the diagnosis should be verified and a simple trephine opening disclosed a membrane 6 mm in thickness consistent with that associated with a subdural hematoma

It appears that this case represents another example of a spontaneously subsiding subdural hematoma The operative findings indicate that the surface accumulation was not simply a subdural hydroma which is not accompanied by thick membrane formation Similar cases have been previously reported by AMBROSETTO (1962) and by GANNON COOK and BROWDER 1962) The frequency with which spontaneous resolution may occur is not known It seems logical that it would occur in certain instances as we have clearly demonstrated that subdural accumulation and cerebral displacement is frequently present after surgical drainage of a subdural hematoma

Discussion

Two previous studies comparable to this investigation should be mentioned PARKINSON & CHOCKINOV in 1960 observed the migration of silver clips placed on the cortex and dura With chronic hematomas a 2 to 5 mm reduction of the arterial displacement occurred during the first 24 hours and during the next 10 days there was very little further reduction although the patients continued to improve The authors concluded that the initial few millimeters is all that is needed to initiate recovery Our observations would support this concept but we believe that subsequent recovery is due to continued midline migration which is largely the result of edema of the involved hemisphere

In 1962 COOK BROWDER and CARTER reported a series of encephalograms on 22 patients with post traumatic hematomas and 1 hydroma In patients treated by craniotomy the shift lasted a shorter time and the authors mentioned persistence of subdural accumulation as a factor contributory to the midline shift

Thus each of the above methods of study measures a separate factor in post operative recovery but neither measures both factors The present authors believe that persistence of midline shift and gradual neurologic recovery are due to a combination of subdural reaccumulation and underlying cerebral swelling Resolution of these components occurs at independent rates Carotid angiography provides a method of demonstrating the two components simultaneously and therefore contributes to understanding the post operative recovery process

BROWDER & RABINER (1951) have written extensively about the cerebral edema which exists beneath a subdural hematoma They demonstrated focal subcortical swelling beneath hematomas in patients dying after intervals of at least 4 days following trauma while no swelling was noted in patients dying of subdural hematomas in less than 4 days The swelling accounts for 1) rapid neurologic deterioration late after injury 2) failure of prompt clinical recovery

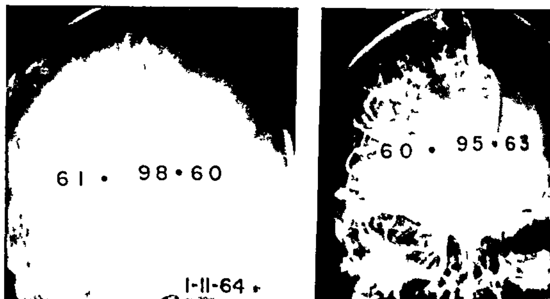


Fig 3 Case 3 Pre and post operative right carotid angiograms show only slight change of vascular displacement despite almost complete neurologic recovery The figures at left indicate distance of sylvian point from inner skull table Surgical drainage was done on Jan 11 1964

with the angiographic findings is hazardous since it seems quite probable in view of pre operative improvement that cerebral contusion was responsible for some of the deficit Never theless it appears that contusion and/or swelling of the hemisphere accounts for most of the neurologic disturbance rather than the surface pressure

Case 3 B O a 32 year old female a chronic alcoholic had fallen several times and com plained of headache for about 7 days before admission to the hospital on Jan 11 1964 During the 2 days prior to admission she had gradually become less responsive On admission she was comatose had dilatation of the right pupil and right hemiparesis Carotid angiography demonstrated the presence of a large right subdural hematoma which was evacuated immedi ately On the following day she was markedly improved and awake with no motor weakness Five days after surgery a post operative angiography was carried out (Fig 3)

The significance of this case is the striking clinical recovery despite continued presence of marked shift of the pericallosal artery and inward displacement of the sylvian point It would appear that surgical intervention relieved the critical degree of intracranial displacement only It is possible that if she had never reached this critical displacement initially spontaneous recovery might have occurred At all events the observations in this case emphasize the lack of predictable relationship between intracranial vascular displacement and clinical manifesta tions

Case 4 H K a 60 year old male was admitted to the hospital on March 24 1964 because of confusion and disorientation associated with a history of chronic alcoholism Examination revealed aphasia and pathologic reflexes on the right Roentgenograms disclosed a pineal shift from left to right and carotid angiography showed a subdural hematoma Since the patient was demonstrating no neurologic deterioration it was decided to postpone surgical interven tion During the ensuing 6 weeks 5 angiographies were done and there was gradual return of

ont l hématome a été évacué l artère péricalleuse revient à sa place normale en 2 à 4 emaines La persistance d un déplacement de cette artère après l opération est due à l associa ion d un oedème cérébral et d un nouvel épanchement sous dural ces facteurs disparaissent vec des vitesses indépendantes Ces mêmes facteurs ainsi que l insuffisance vasculaire due à la ompression contribuent au déficit neurologique et a sa disparition post-opératoire

REFERENCES

AMBROSETTO C Post traumatic subdural hematoma Arch Neurol 6 (1962) 287

BROWDER E J and RABINER A M Regional swelling of the brain in subdural hematoma Ann Surg 134 (1951) 369

COOK A W BROWDER E J and CARTER W B Cerebral swelling and ventricular alterations following evacuation of intracranial extracerebral hematoma J Neurosurg 19 (1962) 419

GANNON W E COOK A W and BROWDER E J Resolving subdural collections J Neurosurg 19 (1962) 865

LINDENBERG R Compression of brain arteries as pathogenetic factors for tissue necrosis and their areas of predilection J Neuropath Exp Neurol 14 (1955) 223

PARKINSON D and CHOCKINOV H Subdural hematomas some observations on their post operative course J Neurosurg 17 (1960) 901

after evacuation of the hematoma, and 3) fluctuation of signs during the period of deterioration. The mechanism of swelling has never been adequately explained but is probably not due solely to venous obstruction.

Three patients in the present series have shown some interference with filling of the pericallosal artery in the presence of a subdural hematoma with subsequent filling after hematoma evacuation. The possibility exists that these may have been chance occurrences but the authors are inclined to the belief that some vascular interference resulted from the shift of intracranial contents. LINDENBERG (1955) has reported extensive observations on vascular compression during intracranial displacement and noted that the anterior cerebral artery may be compressed by the gyrus recti and that the pericallosal artery is compressed by herniation beneath the falx. Whatever the mechanism of compression its presence may contribute to the neurologic deficit and the critical degree of displacement which causes neurologic decompensation may be that which produces sufficient vascular insufficiency.

SUMMARY

Observations in angiographic studies on 19 patients with subdural hematomas are recorded. Eighteen underwent surgical evacuation while 1 demonstrated spontaneous hematoma disappearance. In patients whose hematomas were drained the pericallosal artery returned to normal position in 2 to 4 weeks in most instances. Continued post operative displacement is due to a combination of cerebral edema and subdural reaccumulation; these factors subside at independent rates. These same factors, as well as vascular insufficiency from compression, contribute to the neurologic deficit and its post operative subsidence.

ZUSAMMENFASSUNG

Angiographischen Studien bei 19 Patienten mit subduralen Hamatomen werden berichtet. Achtzehn wurden operiert, wahrend sich in einem Fall das Hamatom spontan zuruckbildete. Bei den Patienten, bei denen die Hamatome drainiert wurden, kehrte die Art. pericallosa in den meisten Fallen in 2 bis 4 Wochen zur normalen Lage zuruck. Fortdauernde postoperative Verlagerung ist auf eine Kombination von cerebralem Ödem und subduraler Wiederauffullung zuruckzufuhren. Diese Faktoren bilden sich unabhangig voneinander mit verschiedener *Geschwindigkeit zuruck. Dieselben Faktoren,* wie auch vaskulare Insuffizienz nach einer Kompression, leisten zum neruologischen Ausfallsymptom und seiner postoperativer Ruckbildung einen Beitrag.

RÉSUMÉ

Les auteurs présentent des remarques sur l'étude angiographique de 19 cas d'hématome sous dural. L'évacuation chirurgical de l'hématome a été faite dans dix huit cas et la disparition spontanée de l'hématome s'est produite dans un cas. Chez la plupart des malades

dont l hématome a été évacue l artere péricalleuse revient à sa place normale en 2 à 4 semaines La persistance d un déplacement de cette artere apres l opération est due à l associa tion d un oedème cérébral et d un nouvel épanchement sous-dural ces facteurs disparaissent avec des vitesses indépendantes Ces memes facteurs ainsi que l insuffisance vasculaire due à la compression contribuent au deficit neurologique et à sa disparition post opératoire

REFERENCES

AMBROSETTO C Post traumatic subdural hematoma Arch Neurol 6 (1962) 287

BROWDER E J and RABINER A M Regional swelling of the brain in subdural hematoma Ann Surg 134 (1951) 369

COOK A W BROWDER E J and CARTER W B Cerebral swelling and ventricular alterations following evacuation of intracranial extracerebral hematoma J Neurosurg 19 (1962) 419

GANNON W E COOK A W and BROWDER E J Resolving subdural collections J Neurosurg 19 (1962) 865

LINDENBERG R Compression of brain arteries as pathogenetic factors for tissue necrosis and their areas of predilection J Neuropath Exp Neurol 14 (1955) 223

PARKINSON D and CHOCKINOV H Subdural hematomas some observations on their post operative course J Neurosurg 17 (1960) 901

after evacuation of the hematoma, and 3) fluctuation of signs during the period of deterioration. The mechanism of swelling has never been adequately explained but is probably not due solely to venous obstruction.

Three patients in the present series have shown some interference with filling of the pericallosal artery in the presence of a subdural hematoma with subsequent filling after hematoma evacuation. The possibility exists that these may have been chance occurrences but the authors are inclined to the belief that some vascular interference resulted from the shift of intracranial contents. LINDENBERG (1955) has reported extensive observations on vascular compression during intracranial displacement and noted that the anterior cerebral artery may be compressed by the gyrus recti and that the pericallosal artery is compressed by herniation beneath the falx. Whatever the mechanism of compression its presence may contribute to the neurologic deficit and the critical degree of displacement which causes neurologic decompensation may be that which produces sufficient vascular insufficiency.

SUMMARY

Observations in angiographic studies on 19 patients with subdural hematomas are recorded. Eighteen underwent surgical evacuation while 1 demonstrated spontaneous hematoma disappearance. In patients whose hematomas were drained the pericallosal artery returned to normal position in 2 to 4 weeks in most instances. Continued post operative displacement is due to a combination of cerebral edema and subdural reaccumulation; these factors subside at independent rates. These same factors, as well as vascular insufficiency from compression, contribute to the neurologic deficit and its post operative subsidence.

ZUSAMMENFASSUNG

Angiographischen Studien bei 19 Patienten mit subduralen Hamatomen werden berichtet. Achtzehn wurden operiert, während sich in einem Fall das Hamatom spontan zuruckbildete. Bei den Patienten, bei denen die Hamatome drainiert wurden, kehrte die Art. pericallosa in den meisten Fallen in 2 bis 4 Wochen zur normalen Lage zuruck. Fortdauernde postoperative Verlagerung ist auf eine Kombination von cerebralem Ödem und subduraler Wiederauffullung zuruckzufuhren. Diese Faktoren bilden sich unabhangig voneinander mit verschiedener Geschwindigkeit zuruck. Dieselben Faktoren, wie auch vaskulare Insuffizienz nach einer Kompression, leisten zum neruologischen Ausfallsymptom und seiner postoperativer Ruckbildung einen Beitrag.

RÉSUMÉ

Les auteurs présentent des remarques sur l'étude angiographique de 19 cas d'hématome sous dural. L'évacuation chirurgical de l'hématome a été faite dans dix huit cas et la disparition spontanée de l'hématome s'est produite dans un cas. Chez la plupart des malades

agent intended to act locally upon the vascular bed or parenchyma of the cord no matter how administered These considerations led them to conclude that any hope for an effective therapy for the adverse effects of roentgen contrast agents would reside in prophylactic rather than remedial approaches

In a series of titrations of the toxicity of various dilutions of fixed volume per kilogram doses of Na acetrizoate they were impressed by two observations (40 62) 1) That concentration was the major factor in the production of injury and 2) correlation between progressive concentration and injury was not parallel Instead there was an abrupt demarcation between innocuous and toxic effects almost approaching an all or none relationship in some tests This non linear relationship could be readily explained by the vasotoxic reaction as follows even an instantaneous exposure of the vascular bed of the cord to a toxic concentration of contrast agent will initiate a series of circulatory events leading to irreversible tissue injury The vasotoxic reaction of itself will increase the application time five to tenfold and the subsequent changes in vascular dynamics of the cord will further intensify the injury (42) It was observed also that the supine position during injection favored the production of spinal cord injury an effect interpreted as the result of differential gravitational flow of the contrast agent with a resultant higher concentration reaching the vascular bed of the cord

Holding that all contrast agents were capable of producing a necrotizing lesion if they reached the vascular bed of organs in the mainstream of their flow in concentrations approaching the high initial level required for angiography they initiated a series of studies exploring means of protecting recipient subjects (24 64) Information derived from these investigations would also provide insight into the mechanisms of tissue injury caused by these substances Measuring therapeutic action against the rigorous test of a 2 ml/kg dose of 70 % Na acetrizoate (Urokon) in their experimental model of retrograde abdominal aortography they observed dramatic protective effects after prophylactic administration of a group of vasodepressor drugs of varied loci of action These included two local analgesics (Procaine HCl Carbocaine HCl) a ganglionic blocking agent (trimethaphan camphor sulfonate [Arfonad]) and a smooth muscle relaxant (Papaverine) Considering that they were dealing with a concentration dependent toxic action they concluded that the protective effect of these vasodepressor drugs resulted from the diversion of the intra aortic injection mass to the periphery hence diluting it below toxic levels in the vascular bed of the spinal cord

If these interpretations of the mechanism of protective action of vasodepressor agents against neurotoxic effects of contrast agents are correct it would be expected that a converse effect — a potentiation of the neurotoxicity of contrast

FROM THE PATHOLOGY DEPARTMENTS OF DARTMOUTH MEDICAL SCHOOL, HANOVER, NEW HAMPSHIRE AND MEDICAL COLLEGE OF VIRGINIA, RICHMOND, VIRGINIA, U S A

VASOPRESSOR POTENTIATION OF NEUROTOXICITY IN EXPERIMENTAL AORTOGRAPHY

Implications regarding pathogenesis of contrast medium injury

by

GEORGE MARGOLIS and THEODORE G YERASIMIDES

In 1956 MARGOLIS and associates introduced a new experimental model (39, 60) for the study of the pathogenesis of the injury to the nervous system produced by contrast media used in diagnostic angiology Employing retrograde abdominal aortography in the dog, and using the spinal cord as the site of study they described, for the first time in experimental animals, the full evolution of the contrast medium lesion From these observations it was manifest that existing concepts of the injury as a transient vascular disorder were no longer adequate and had to be revised to include a severe necrotizing effect

Continuing their studies with this model (41, 42), they described in association with the injury a severe irreversible disruption of the circulation of the cord, immediate in onset, and characterized by an abrupt arrest of the toxic injection mass, an immediate impairment of vascular permeability barriers, torpid blood flow with development of severe sludging and a persistent elevation of vascular resistance in the area of injury The changes took place in the absence of demonstrable vasospasm These disturbances in vasomotion were so severe as to constitute, in their opinion, a formidable obstacle to any therapeutic

Table 2

Potentiation by Levophed of neurotoxic action of fixed volume intra aortic dose of varying concentrations of Hypaque Angio Conray and Conray

First injection 2 ml/kg		Second injection 2 ml/kg		No of dogs	Posture	Convulsive response		Neurologic deficit				Anatomic lesion grade						Died
Agent	Dose mg	Agent	Concentration (%)			Neg	Pos	None	Mild	Mod	Severe	0	1	2	3	4	5	
		Hypaque	90	5	Supine	5		5				2	2	1				
Levophed	1	Hypaque	90	5	»	1	4				5					1	4	
Levophed	1	Hypaque	75	5	»	1	4				5					2	3	
Levophed	1	Hypaque	50	6	»	4	2		1	1	3				2	1	2	1
Levophed	1	Hypaque	40	6	»	6		1	2		2			1	[illegible]	1		1
Levophed	1	Hypaque	35	5	»	5		5					2	3				
		Hypaque	90	5	Prone	5		5				4	1					
Levophed	1	Hypaque	90	5	»	1	4				5				1	3	1	
Levophed	1	Hypaque	75	6	»	4	2	1	1	1	3		1	1	2	2		
Levophed	1	Hypaque	50	5	»	4	1	4			1	2	1	2				
Levophed	1	Hypaque	40	5		5		5				2	3					
		Angio Conray	80	6	Supine	5	1	6					4	2				
Levophed	1	Angio Conray	80	5	»	1	4				5					1	4	
Levophed	1	Angio Conray	50	5	»	1	4				5					3	2	
Levophed	1	Angio Conray	40	5	»	5					5				2	1	2	
Levophed	1	Angio Conray	30	5	»	5		4	1			4		1				
		Conray	60	5	»	5		5				5						
Levophed	1	Conray	60	5	»	5				2	3			1	4			
Levophed	1	Conray	50	5	»	5		2			3		2		3			
Levophed	1	Conray	40	5	»	5		5				5						

Administered 30 sec after 1st injection

Death occurred within 8 hrs after administration of contrast agent

Conray (Na iothalamate 80 %) and Conray (methylglucamine iothalamate 60 %). *In these* tests the agents were injected manually or by an air-driven syringe via a retrograde *femoral* catheter passed *into the* abdominal aorta to the level of the 2nd lumbar vertebral body *at a* rate of 5 ml per sec. Two programs of administration of contrast agents were used (*Tables* 1–3). In one the *volume* dose was maintained at 2 ml/kg body weight and the concentration of each agent was *progressively lowered* from the highest level available. In the *other* the volume dose was *progressively* reduced by decrements of 50 % and the concentration *of* each agent was maintained. *In* each program two test series were performed. *In the first* the contrast agent was *administered* without a preparatory injection. In the second the contrast agent was preceded 30 *seconds* by an injection of 1 mg of levarterenol (Levophed).

Table 1

Potentiation by Levophed of neurotoxic action of fixed volume intra aortic doses of varying concentrations of Urokon

First injection 2 ml/kg: Agent	Dose mg or concentration	Second injection[1] 2 ml/kg: Agent	Concentration % or dose	No of dogs	Posture	Convulsive response: Neg	Pos	Neurologic deficit: None	Mild	Mod	Severe	Anatomic lesion grade: 0	1	2	3	4	5	Del
		Urokon	70	8	Supine		8				7					4	3	1
		Urokon	50	5	»		5			1	4					3	2	
		Urokon	40	5	»	1	4	1			4			1	2	2		
		Urokon	35	6	»	6		5				3	2					1
Levophed	1	Urokon	50	5	»	3	2				5					1	3	1
Levophed	1	Urokon	40	5	»	2	3				3					1	2	2
Levophed	1	Urokon	35	5	»	2	3				5					3	2	
Urokon	35 %	Levophed	1 mg	5	»	5		4		1		2	2	1				
Levophed	1	Urokon	25	7	»	2	5		1	2	4			1	2	2	2	
Levophed	1	Urokon	20	5	»	4	1	4	1			1	1	3				
Levophed	1	Urokon	15	5	»	5		5				2	2	1				
		Urokon	70	7	Prone	3	2	3		3			1	2	3			1
		Urokon	50	5	»	5		5				2	1	2				
		Urokon	35	5	»	5		5				4	1					
Levophed	1	Urokon	70	7	»	5	2				6					2	4	1
Levophed	1	Urokon	35	7	»	3	2				5				2		3	
Urokon	35 %	Levophed	1 mg	5	»	5		5				2	3					
Levophed	1	Urokon	25	5	»	5		2			3	1	1		1	2		
Levophed	1	Urokon	20	5	»	5		5				3	2					

[1] Administered 30 sec after 1st injection

[2] Death occurred within 8 hrs after administration of contrast agent

agents — would be obtained in this experimental model if a vasopressor agent were used instead of vasodepressor drugs The present report describes results of studies testing this postulate, and further exploration of the pathogenesis and therapeutics of contrast agent injury

Experimental procedure

The procedure used followed the same plan reported previously (24 63) using the canine abdominal aortography model with the spinal cord as the principal test site Four contrast agents were used in commercially available concentrations namely Urokon (Na acetrizoate 70 %) Hypaque (Na [30 %] and methylglucamine [60 %] diatrizoate 90 %) Angio-

Table 2

Potentiation by Levophed of neurotoxic action of fixed volume intra aortic doses of varying concentrations of Hypaque Angio Conray and Contray

First injection 2 ml kg		Second injection[a] ? ml/kg		No of dogs	Posture	Convulsive response		Neurologic deficit				Anatomic lesion grade						Died[b]
Agent	Dose mg	Agent	Concentration (%)			Neg	Pos	None	Mild	Mod	Severe	0	1	2	3	4	5	
			90	5	Supine	5		5				2	2	1				
Levophed	1		90	5	»	1	4				5					1	4	
Levophed	1		75	5	»	1	4				5					2	3	
Levophed	1		50	6	»	4	2		1	1	3				2	1	2	1
Levophed	1		40	6	»	6		1	2		2			1	3	1		1
Levophed	1	Hypaque	35	5	»	5		5					2	3				
			90	5	Prone	5		5				4	1					
Levophed	1		90	5	»	1	4				5				1	3	1	
Levophed	1		75	6	»	4	2	1	1	1	3		1	1	2	2		
Levophed	1		50	5	»	4	1	4			1	2	1	2				
Levophed	1		40	5	»	5		5				2	3					
			80	6	Supine	5	1	6					4	2				
Levophed	1		80	5	»	1	4				5					1	4	
Levophed	1	Angio-Conray	50	5	»	1	4				5					3	2	
Levophed	1		40	5	»	5					5				2	1	2	
Levophed	1		30	5	»	5		4	1			4		1				
			60	5	»	5		5				5						
Levophed	1	Conray	60	5	»	5				2	3			1	4			
Levophed	1		50	5	»	5		2			3		2		3			
Levophed	1		40	5	»	5		5				5						

[a] Administered 30 sec after 1st injection

[b] Death occurred within 8 hrs after administration of contrast agent

Conray (Na iothalamate 80 %) and Conray (methylglucamine iothalamate 60 %). In these tests the agents were injected manually or by an air-driven syringe via a retrograde femoral catheter passed into the abdominal aorta to the level of the 2nd lumbar vertebral body at a rate of 5 ml per sec. Two programs of administration of contrast agents were used (Tables 1–3). In one the volume dose was maintained at 2 ml/kg body weight and the concentration of each agent was progressively lowered from the highest level available. In the other the volume dose was progressively reduced by decrements of 50 % and the concentration of each agent was maintained. In each program two test series were performed. In the first the contrast agent was administered without a preparatory injection. In the second the contrast agent was preceded 30 seconds by an injection of 1 mg of levarterenol (Levophed)

Table 3

Potentiation by Levophed of neurotoxic action of varied volume intra-aortic doses of concentrated solutions of Urokon, Hypaque, Angio-Conray and Conray

First injection: Agent	Dose mg	Dose ml/kg[3]	Second injection[1]: Agent	Conc (%)	Dose ml/kg	No. of dogs	Posture	Convulsive response: Neg	Pos	Neurologic deficit: None	Mild	Mod	Severe	Anatomic lesion grade: 0	1	2	3	4	5	Dead[2]
			Urokon	70	1	8	Supine		7				7				2	1	4	
			Urokon	70	0.5	6	»	1	5	1	2		3	1	1	1		2	1	
			Urokon	70	0.25	5	»	3	2	3	1		1	1	2	1		1		
Levophed	1	0.25	Urokon	70	0.25	5	»	1	4				5				1		4	
Levophed	1	0.125	Urokon	70	0.125	5	»	3	2	1			4	1			1	1	2	
Levophed	1	0.06	Urokon	70	0.06	5	»	5		1	1	1	1		3			1		1
Levophed	1	0.5	Hypaque	90	0.5	6	»	2	4				5					2	3	1
Levophed	1	0.25	Hypaque	90	0.25	5	»	4	1		1		4			1		1	3	
Levophed	1	0.125	Hypaque	90	0.125	5	»	5		4			1	4				1		
Levophed	1	0.25	Angio-Conray	80	0.25	5	»	5		3			2	3				2		
Levophed	1	0.125	Angio-Conray	80	0.125	5	»	5		3		1	1	3		1			1	
Levophed	1	1.0	Conray	60	1.0	5	»	5		5				5						

[1] Administered 30 sec after 1st injection

[2] Death occurred within 8 hrs following administration of contrast agent

[3] Volume dose = 1 ml or more

diluted to an equivolume dose and administered via the same route and at the same rate. The route of the preparatory injection coupled with the interval between it and the administration of the contrast agent was chosen 1) to expose the target vascular bed to the first arterial circuit of the vasoactive agent, hence to its maximal influence, and 2) to allow time for its systemic action to be initiated. At the end of the preparatory injection the catheter was emptied by flushing and was refilled with saline. A single test was carried out on each animal.

As in previous experiments control studies were used, *with the order of injection of test* substances reversed, the vasoactive agent following the contrast material. In these studies the primary objective was to observe the influence of a vasopressor agent upon the neurotoxic action of contrast agents. Comparison of relative neurotoxicity of the various media used was but an incidental feature of the study. Accordingly, in the titrations of progressively reduced

concentrations in one series and volume doses in the other series these decrements were of smaller order in tests with Urokon and Hypaque agents used earlier in the study than with Angio-Conray and Conray which were tested later Overtly healthy adult mongrel dogs of both sexes weighing 6 to 20 kg were used Anesthesia was induced by intravenous pentobarbital or by fluothane inhalation With each injection the immediate neurologic and cardiorespiratory responses were noted In selected animals arterial pressure changes were recorded on a Honeywell Visicorder Upon recovery from the anesthesia and daily thereafter observations of the neurologic status were made After a period usually of 5 to 7 days the animals were sacrificed by an overdose of nembutal for pathologic study after the manner previously reported (39) The cord was removed fixed in neutral formalin and sectioned transversely at 0 3 to 0 5 cm intervals The gross features of the cord were diagrammed on a model recording the transverse and longitudinal extent of the lesions Confirmation of the gross observations was made with study of selected microscopic sections six or more for each specimen Although the pathologic studies were focused primarily upon neurotoxic effects of the contrast agents with the spinal cord as the target site gross surveys were made of somatic organs for overt damage and histological examinations of the kidneys were done on all the test animals Hematoxylin eosin stains were routinely used

The immediate neurologic response the post injection neurologic status and the resultant anatomic changes in the spinal cord were classified by a grading system established in earlier studies as reported below

Convulsive response This was graded as negative or positive according to these criteria

Negative — No convulsion is recognized

1 No response

2 Brief (10 sec or less) feeble flexion and/or extension of the trunk and/or hind legs and tail without subsequent signs or abnormal irritability or changes in the reflexes

Positive — Convulsive response occurs

1 Prolonged (usually 20 to 50 sec) tonic flexion and/or extension involving the trunk hind limbs and tail and sometimes the forelimbs and neck without a recognizable clonic phase and followed by a 1 to 15 min period of hyperreflexia during which clonus may be elicited by tactile stimulation or

2 Prolonged (usually 20 to 50 sec) tonic flexion and/or extension involving the trunk hind limbs and tail sometimes forelimbs and neck followed by a clonic phase lasting from 30 sec to 5 min followed by severe hyperreflexia of 3 to 20 min duration

Neurologic defect

None — No alteration of function is observed

Mild — A mild paresis of the hind legs is produced which is not apparent until the animal is exercised This dysfunction usually disappears over the course of 3 to 5 days

Moderate — Paraparesis is more marked than above and the animal may show weakness in the hind legs with impairment of locomotion which usually improves over the course of 3 to 5 days

Severe — A paraplegia usually spastic but sometimes flaccid is present

Anatomic lesions These were considered the most sensitive and definitive criteria of injury

Grade 0 — No lesions are demonstrable

Grade 1 — There are sparsely scattered microscopic foci of destruction affecting gray or white matter present in one or more sections of spinal cord

Grade 2 — There are multiple small (1 to 2 mm) scattered foci of destruction of gray matter with or without involvement of white matter or spinal nerve roots distributed over 5 to 10 cm of spinal cord

Grade 3 — Extensive focal discrete or confluent zones of destruction of gray matter with or without involvement of white matter or spinal nerve roots extending over 5 to 10 cm of spinal cord are present

Grade 4 — Complete or nearly complete devastation of gray matter with or without involvement of white matter or spinal nerve roots involving from 10 to 18 cm of cord is observed

Grade 5 — There is complete or essentially complete transverse necrosis of the spinal cord often with extensive destruction of spinal nerve roots involving from 10 to 18 cm of cord

Results

The results of these studies are summarized in Tables 1 to 3 and Figs 1 to 5 At 2 ml/kg volume doses the concentrated solutions of these contrast agents, except for Urokon, were without overt neurotoxic action or were but minimally noxious, even for supinely positioned animals Urokon, however (Tables 1 and 3, Figs 1 and 2) produced severe cord injury at concentrations down to 40 %, with an abrupt fall off in toxicity at 35 % When administered to pronely positioned animals its neurotoxic action was strikingly reduced, as exemplified by a comparison of the effects of the 50 % concentration upon animals in these two postures When concentration was maintained and volume dose progressively reduced Urokon retained its neurotoxic potential at low doses, producing frequent severe cord injury at 0 5 ml/kg and occasional severe injury at 0 25 ml/kg When Levophed was administered directly prior to the contrast agents, without exception a striking potentiation of neurotoxicity was produced At 2 ml/kg doses, Urokon retained its toxicity until the concentration was reduced below 25 %, and the favourable influence of the prone posture was overcome Further, incredibly small doses of 70 % Urokon were rendered toxic, devastating spinal cord injury almost invariably resulting with 0 125 ml/kg doses and occasionally with 0 06 ml/kg doses The less noxious contrast agent, Hypaque, in 2 ml/kg doses was rendered severely neurotoxic by Levophed at concentrations of 40 % and above for the supinely positioned animal and at 75 % with the dog in the prone position 90 % Hypaque retained this neurotoxic action at a volume dose of 0 25 ml/kg and was occasionally injurious at 0 125 ml/kg (Tables 2 and 3, Fig 3) Similarly, Angio Conray, administered in 2 ml/kg doses following Levophed, was severely neurotoxic at 40 % and above, 80 % Angio Conray was unpredictably noxious at 0 25 and 0 125 ml/kg doses (Tables 2 and 3 Fig 4)

Conray, administered in 2 ml/kg doses following Levophed exerted a variable and generally severe neurotoxic action at 60 % concentration At this volume dose the toxicity of this agent was reduced at 50 % and eliminated at 40 %

Levophed Order of injection	Urokon concentration (%)	Posture of dog	Cord lesion (each section indicates one animal)
—	50	Supine	
—	50	Prone	
—	40	Supine	
—	35	Supine	
1st	35	Supine	
2nd	35	Supine	
—	35	Prone	
1st	35	Prone	
1st	25	Supine	
1st	0	Supine	

Fig. 1. Potentiation by Levophed (1 mg) of neurotoxic action of fixed volume (2 ml/kg) intra-aortic doses of varying concentration of Urokon.

Grade 2 — There are multiple small (1 to 2 mm) scattered foci of destruction of gray matter with or without involvement of white matter or spinal nerve roots distributed over 5 to 10 cm of spinal cord

Grade 3 — Extensive focal discrete or confluent zones of destruction of gray matter with or without involvement of white matter or spinal nerve roots extending over 5 to 10 cm of spinal cord are present

Grade 4 — Complete or nearly complete, devastation of gray matter with or without involvement of white matter or spinal nerve roots involving from 10 to 18 cm of cord is observed

Grade 5 — There is complete or essentially complete transverse necrosis of the spinal cord often with extensive destruction of spinal nerve roots involving from 10 to 18 cm of cord

Results

The results of these studies are summarized in Tables 1 to 3 and Figs 1 to 5 At 2 ml/kg volume doses the concentrated solutions of these contrast agents, except for Urokon, were without overt neurotoxic action or were but minimally noxious, even for supinely positioned animals Urokon, however (Tables 1 and 3, Figs 1 and 2) produced severe cord injury at concentrations down to 40 %, with an abrupt fall off in toxicity at 35 % When administered to pronely positioned animals its neurotoxic action was strikingly reduced, as exemplified by a comparison of the effects of the 50 % concentration upon animals in these two postures When concentration was maintained and volume dose progressively reduced Urokon retained its neurotoxic potential at low doses, producing frequent severe cord injury at 0 5 ml/kg and occasional severe injury at 0 25 ml/kg When Levophed was administered directly prior to the contrast agents, without exception a striking potentiation of neurotoxicity was produced At 2 ml/kg doses, Urokon retained its toxicity until the concentration was reduced below 25 %, and the favourable influence of the prone posture was overcome Further, incredibly small doses of 70 % Urokon were rendered toxic, devastating spinal cord injury almost invariably resulting with 0 125 ml/kg doses and occasionally with 0 06 ml/kg doses The less noxious contrast agent, Hypaque, in 2 ml/kg doses was rendered severely neurotoxic by Levophed at concentrations of 40 % and above for the supinely positioned animal and at 75 % with the dog in the prone position, 90 % Hypaque retained this neurotoxic action at a volume dose of 0 25 ml/kg and was occasionally injurious at 0 125 ml/kg (Tables 2 and 3, Fig 3) Similarly, Angio Conray, administered in 2 ml/kg doses following Levophed, was severely neurotoxic at 40 % and above, 80 % Angio Conray was unpredictably noxious at 0 25 and 0 125 ml/kg doses (Tables 2 and 3, Fig 4)

Conray, administered in 2 ml/kg doses following Levophed, exerted a variable and generally severe neurotoxic action at 60 % concentration At this volume dose the toxicity of this agent was reduced at 50 % and eliminated at 40 %

Levophed Order of injection	Hypaque Concentration ( )	Hypaque ml/kg	Cord lesion (each section indicates one animal)
–	90	2	
1st	90	2	
1st	50	2	
1st	40	2	
1st	35	2	
1st	90	0 5	
1st	90	0 25	
1st	90	0 125	

Fig 3 Potentiation by Levophed (1 mg) of neurotoxic action of intra aortic Hypaque administered in supine ly positioned dogs

were recorded exhibited a rise in blood pressure and widening of pulse pressure Further a pressor response to the subsequent contrast agent was sometimes observed This latter reaction had not been encountered in previous studies with contrast agents where a mild depressor effect had been the common observation (42) The varying pressure responses to contrast agents with and without vasoactive drugs are summarized elsewhere (64)

Levophed Order of injection	Urokon ml/kg	Cord lesion (each section indicates one animal)
—	1	
—	0 5	
	0 25	
1st	0 25	
1st	0 125	
1st	0 006	

Fig 2 Potentiation by Levophed (1 mg) of neurotoxic action of varied volume intra aortic doses of 70 % Urokon administered to supinely positioned animals

concentration Reduction of the volume dose of 60 % Conray to 1 ml/kg virtually removed its toxic action

On the other hand, when Levophed was administered following instead of preceding a contrast agent no potentiation of neurotoxic action occurred (Table 1, Fig 1) Of 10 dogs to whom the sequence of 2 ml/kg of 35 % Urokon then Levophed, was administered, none exhibited evidence of severe functional or anatomical lesions

In this large series of animals none demonstrated gross alterations of the somatic organs Mild degrees of kidney injury, consisting of a slight increase in glomerular permeability to proteins and rare foci of tubular necrosis were occasionally seen These changes were not increased in severity in the animals to whom Levophed was administered The injection of Levophed produced regularly an acceleration of heart rate, and the animals in which these variables

Levophed Order of injection	Conray Concentration ( )	Conray ml kg	Cord lesion (each section indicates one animal)
—	60	2	
1st	60	2	
1st	60	1	
1st	50	2	
1st	40	2	

Fig 5 Potentiation by Levophed (1 mg) of neurotoxic action of intra aortic Conray administered to supinely positioned dogs

vascular bed of the spinal cord would be expected With small volume doses however an unpredictable relationship between the injection mass and the variable and infrequent major arterial tributaries to the spinal cord can readily be understood The inhibition of the toxic spinal convulsive reaction to contrast agents by Levophed (Tables 1 and 3) an agent which augments the neurotoxic action of these media points to a direct local depressant action upon the central nervous system by this drug strong enough to block a response which is not inhibited by inhalation anesthetics or by pentobarbital anesthesia

These studies have demonstrated an impressive augmentation in the neurotoxic action of contrast media or from another viewpoint a striking increase in susceptibility of experimental animals to these agents — resulting from the action of vasopressor drug Yet marked as these results are they present but one aspect of the modifying effects of pharmacologic agents A better conception of the magnitude of these influences may be gained by a comparison of these observations with previous studies demonstrating the protective action

Levophed Order of Injection	Angio Conray		Cord lesion (each section indicates one animal)
	Concentration (%)	ml/kg	
—	90	2	
1st	80	2	
1st	40	2	
1st	30	2	
1st	80	0.25	
1st	80	0.125	

Fig 4 Potentiation by Levophed (1 mg) of neurotoxic action of intra aortic Angio Conray administered to supinely positioned dogs

Certain other features of these studies stand out These include the abrupt demarcation between innocuous and severely toxic doses of contrast agents, the variability of the results observed in the low volume dose series, and the unreliability of the convulsive response as an indicator of neurotoxic action in the pharmacologically altered subjects The sharp transition between toxic and non toxic doses is graphically illustrated in the figures (1 to 5) These findings are consistent with previous observations and can be explained, as before (42), by the microcirculatory changes occurring in conjunction with the toxic reaction The variability of the results in the low volume dose studies (Tables 2 to 3) contrast strikingly with the consistency of the effects encountered in the large volume dose studies In the latter series a uniform exposure of the

Levophed Order of injection	Conray Concentration ( )	Conray ml/kg	Cord lesion (each section indicates one animal)
—	60	2	
1st	60	2	
1st	60	1	
1st	50	2	
1st	40	2	

Fig 5 Potentiation by Levophed (1 mg) of neurotoxic action of intra aortic Conray administered to supinely positioned dogs

vascular bed of the spinal cord would be expected With small volume doses however an unpredictable relationship between the injection mass and the variable and infrequent major arterial tributaries to the spinal cord can readily be understood The inhibition of the toxic spinal convulsive reaction to contrast agents by Levophed (Tables 1 and 3) an agent which augments the neurotoxic action of these media points to a direct local depressant action upon the central nervous system by this drug strong enough to block a response which is not inhibited by inhalation anesthetics or by pentobarbital anesthesia

These studies have demonstrated an impressive augmentation in the neurotoxic action of contrast media or from another viewpoint, a striking increase in susceptibility of experimental animals to these agents — resulting from the action of vasopressor drug Yet marked as these results are they present but one aspect of the modifying effects of pharmacologic agents A better conception of the magnitude of these influences may be gained by a comparison of these observations with previous studies demonstrating the protective action

of vasodepressor substances against contrast agent injury in this experimental aortography model. At one extreme, the highly toxic medium, Urokon, was rendered virtually innocuous, even at 2 ml/kg intra-aortic doses of the 70 % concentration. At the other extreme, volume doses of 70 % Urokon as small as 0.125 ml/kg were made highly neurotoxic, as were *concentrations as low as* 25 % in 2 ml/kg doses. Hypaque 90 %, otherwise non-toxic at 2 ml/kg doses, produced severe spinal cord injury at 0.25 ml/kg doses when administered during an active vasopressor stimulus. Angio Conray 80 %, ordinarily innocuous at 2 ml/kg doses, was variably toxic at 0.25 ml/kg doses when administered following Levophed. These influences are graphically depicted by a comparison of diagrams of paired experiments demonstrating, on the one hand a protective effect from a previously reported study (Fig. 6) and on the other, a potentiating action (Fig. 7).

The intensification of the toxic potential of Conray by Levophed was less dramatic than with the other contrast media, pointing to a greater margin of safety in the use of this contrast medium in diagnostic angiology, a property considered to be related to the use of methyl glucamine rather than sodium as the vehicle for this agent.

Discussion

By pharmacologic induction of altered reactivity of the vascular system, it has been possible, using a canine aortography model, to protect the spinal cord from injury by roentgen contrast agents and, conversely, to potentiate the neurotoxic action of these agents. The potentiating action of a vasopressor *drug confirms the authors' predictions based upon observations* of the protective effect of vasodepressor substances, and supplies a vital link in our knowledge of the nature of contrast medium injury (64). The import of these observations is emphasized by the broad differences in toxicities of various contrast agents under these modifying influences. The utterly small amounts of contrast media productive of neurotoxic effects in these studies (0.06 to 0.125 ml/kg or 1.2 to 2.5 ml for a 20 kg dog) adds further dimension to the concept of the potential toxicity of these agents. Nowhere in the experimental literature has so injurious *an effect been produced on so diffuse a target by such inconsiderable* quantities of contrast agents. The amounts stand in sharp contrast to the volume doses used in other meaningful studies of the toxicity of these substances. For example, KUTT and associates (28, 29, 45) exploring effects upon formed *elements,* proteins and electrolytes of the blood injected multiple intracarotid doses of 0.25 to 0.50 ml into rats reaching a total in excess of 6 % of the blood volume. AUSMAN et coll., studying the immediate toxic action of these media upon

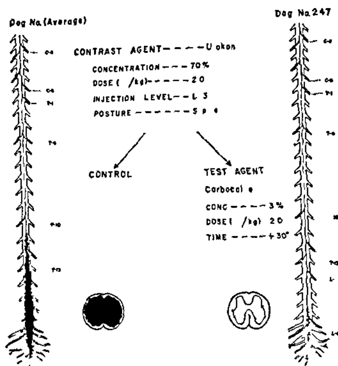


Fig 6 This paired experiment from a previous study (64) demon st ates the protect ve act on of a vasodep essor drug against neurotox c eff cts of ro ntgen contrast agents n the canine aortog aphy model A rep esentati map of the arterial supply of the cord is presented rather than the actual pattern of blood supply for each animal The d of Urokon app ox mating 2/3 the MLD for the intraaort c route is far n e cess of clin cally used doses and poses a most r gorous test of p t ct ve action The blackened areas indicate the transverse and longitud nal extent of the sp nal co d les ons produced in typical control a imals (left) and the virtually complete prophylaxis of this neurotox c ff ct ach eve l by the intra aort c administration of carbocaine 30 s conds pr or to th injection of the contrast agent (right)

vascular endothelium injected quantities as high as 15 ml through the rat aorta At the other extreme volume doses of concentrated agents far larger than those used in clinical aortography are converted into innocuous doses An approximately 10 to 20 fold difference in toxicity of these substances for this experimental model has been demonstrated between the two extremes of modifying influences of vasoactive drugs Additionally, all contrast agents used in this study have been demonstrated to have a toxic potential In view

of vasodepressor substances against contrast agent injury in this experimental aortography model. At one extreme, the highly toxic medium, Urokon, was rendered virtually innocuous, even at 2 ml/kg intra-aortic doses of the 70 % concentration. At the other extreme, volume doses of 70 % Urokon as small as 0.125 ml/kg were made highly neurotoxic, as were concentrations as low as 25 % in 2 ml/kg doses. Hypaque 90 %, otherwise non-toxic at 2 ml/kg doses, produced severe spinal cord injury at 0.25 ml/kg doses when administered during an active vasopressor stimulus. Angio-Conray 80 %, ordinarily innocuous at 2 ml/kg doses, was variably toxic at 0.25 ml/kg doses when administered following Levophed. These influences are graphically depicted by a comparison of diagrams of paired experiments demonstrating, on the one hand a protective effect from a previously reported study (Fig. 6) and on the other, a potentiating action (Fig. 7).

The intensification of the toxic potential of Conray by Levophed was less dramatic than with the other contrast media, pointing to a greater margin of safety in the use of this contrast medium in diagnostic angiology, a property considered to be related to the use of methyl glucamine rather than sodium as the vehicle for this agent.

Discussion

By pharmacologic induction of altered reactivity of the vascular system, it has been possible, using a canine aortography model, to protect the spinal cord from injury by roentgen contrast agents and, conversely, to potentiate the neurotoxic action of these agents. The potentiating action of a vasopressor drug confirms the authors' predictions based upon observations of the protective effect of vasodepressor substances, and supplies a vital link in our knowledge of the nature of contrast medium injury (64). The import of these observations is emphasized by the broad differences in toxicities of various contrast agents under these modifying influences. The utterly small amounts of contrast media productive of neurotoxic effects in these studies (0.06 to 0.125 ml/kg or 1.2 to 2.5 ml for a 20 kg dog) adds further dimension to the concept of the potential toxicity of these agents. Nowhere in the experimental literature has so injurious an effect been produced on so diffuse a target by such inconsiderable quantities of contrast agents. The amounts stand in sharp contrast to the volume doses used in other meaningful studies of the toxicity of these substances. For example, KUTT and associates (28, 29, 45) exploring effects upon formed elements, proteins and electrolytes of the blood injected multiple intracarotid doses of 0.25 to 0.50 ml into rats reaching a total in excess of 6 % of the blood volume. AUSMAN et coll., studying the immediate toxic action of these media upon

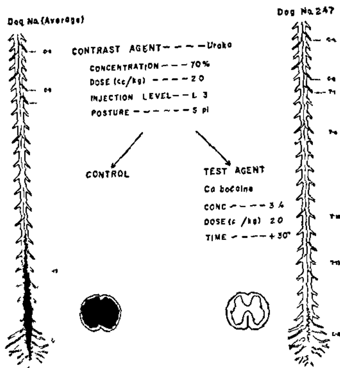


Fig 6 This paired experiment f om a previous study (64) demon strates the protective act on of a vasodepressor drug against neurotoxic effects of roentgen contra t agents n the canine aortography model A representati e map of the arterial supply of the cord is presented rath r than the *actual* pattern of blood supply for each animal The do e of Urok n approximat ng 2/3 the MLD for the intraaortic route i fa in excess of cl nically used doses and poses a most rigorous test of p ot ct ve act on The blackened areas indicate the transverse and longitudinal ex ent of the spinal cord les ons produced in typical control animals (l ft) and the irtually complete prophylaxis of this neuroto ic ffect ach e d by the *intra aortic* admini tration of carboca ne 30 seconds prior to the nj ct on of th contrast agent (right)

vascular endothelium injected quantities as high as 15 ml through the rat aorta At the other extreme volume doses of concentrated agents far larger than those used in clinical aortography are converted into innocuous doses An approximately 10 to 20 fold difference in toxicity of these substances for this experimental model has been demonstrated between the two extremes of modifying influences of vasoactive drugs Additionally all contrast agents used in this study have been demonstrated to have a toxic potential In view

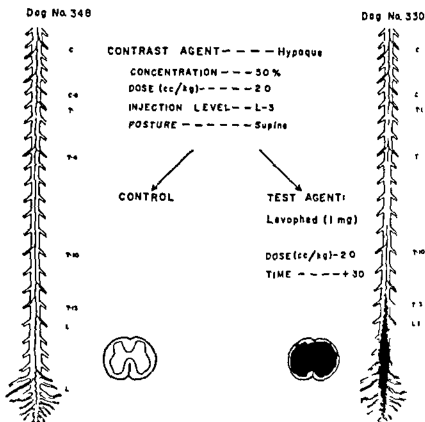


Fig. 7. This paired experiment demonstrates the potentiating action of a vasopressor drug upon neurotoxic effects of roentgen contrast agents in the canine aortography model. A representative map of the arterial supply of the cord is presented rather than the actual pattern of blood supply for individual animals. The spinal cord lesion resulting from the contrast agent is depicted by blackened areas in both longitudinal and transverse diagrams. The dose of Hypaque, which is far below levels which have exhibited even minimal noxious effects (left), provides an unequivocal test of the ability of the vasopressor agent Levophed (levarterenol) to render this experimental model extremely susceptible to the neurotoxic action of contrast agents (right).

of these observations the possibility must be reconsidered that complications of carotid angiography may result from direct toxic action of the contrast agents rather than solely from faulty injection technics and pre-existing vascular disease (52).

These modifying influences of vasoactive agents upon vulnerability of this experimental model to neurotoxic effects of contrast agents are explained, as before (64), on the basis of the differential reactivity of the vascular beds of the somatic organs and those of the nervous system. The latter have a notably

weaker reactivity to physical and to most chemical stimuli excepting the respiratory gases (32, 57) The stronger response of peripheral vessels to vaso active agents could then override and reverse the primary reactions of the neural vascular bed The vascular shunts resulting from these unequal responses to vasoactive agents are schematically presented in Figs 8 and 9 Injected at the height of the vasotonic response to levarterenol a contrast substance would be shunted toward the spinal cord because of the greater resistance to flow in the peripheral vessels The possibility may be considered that these dramatic differences in neurotoxic reaction could signify that vasospasm played a major role in the production of the noxious action of contrast agents Our earlier studies focused particularly upon the role of altered circulatory dynamics in the production of this injury have provided no evidence in support of such an interpretation Rather a striking disturbance in vasomotion characterized by the circulatory events summarized above (42), occurred in the absence of demonstrable vasospasm There is an abundant literature arguing against (6 22 23 35 36) the role of vasospasm in the production of contrast medium injury One paper presents evidence that vasospasm exerts a protective effect (13) Urokon has been demonstrated to open up arteriovenous anastomoses in the extremities (56) and has even been used therapeutically to relieve vasospasm of peripheral vessels (37) Few reports of a vasospastic reaction to contrast agents are presented (8 20 47 63) Our studies offer further argument against vasospasm being a factor in the production of injury based upon the absence of effects upon somatic organs paralleling those observed in the nervous system If a vasospastic response to contrast agents represented the mechanism of production of toxic effects a severe injury to sites such as the kidney where the vascular bed is far more reactive than that of the central nervous system should theoretically have been produced by contrast agents administered at the height of a vasopressor response For the same reason a direct potentiation of toxicity of contrast agents by levarterenol independent of alterations in vascular dynamics is considered unlikely Parenthetically, the absence in these studies of injury to the kidney an organ clearly in the potential target area during aortography (43 50) indicates that a vascular shunt protecting the nervous system has not been created at the peril of important somatic organs The decrease in neurotoxicity of an intra aortically administered contrast agent by turning an animal from the supine to the prone position (18 39 40 60) an effect related to the differential gravitational flow of the iodinated medium rather than to altered circulatory dynamics (41 42) — a protective effect which can be overcome however, by the vaso pressor shunt — emphasizes the lability and sensitivity of this concentration dependent experimental model

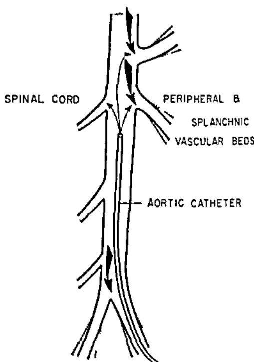


Fig 8 Schematic representation of the redistribution of blood flow produced by vasoactive agents as a result of the differential reactivity of the vascular beds of the somatic organs and those of the nervous system Vasodepressor drugs produce a decreased vascular resistance in the somatic vascular bed diverting a potentially neurotoxic intra aortic injection mass to the periphery hence reducing it below noxious levels in the vascular bed of the spinal cord This protective shunt has been induced by pharmacologic agents with diverse actions including local analgesics a ganglionic blocking drug and a smooth muscle relaxant In view of the fact that the major changes in vascular tonus occur far distal to the depicted vascular beds this diagram errs on the side of simplicity in order to allow a presentation of blood flow In actuality the order of vessels illustrated by this diagram may exhibit changes in caliber in an opposing direction i e a decrease in lumen diameter may occur in the face of peripheral vasodilatation

Our studies present overwhelming evidence of a primary, concentration dependent, immediate, vasotoxic effect of contrast agents This evidence is in agreement with earlier observations of BROMAN et coll (10, 8) that concentration was a major factor in the noxious action of these substances These workers observed that an agent of high concentration remaining in the cerebrovascular bed for but 1 second was more injurious than more dilute agents remaining in the vessels 10 to 70 seconds KILLEN & OWENS (26), measuring renal oxygen availability after Urokon perfusion obtained findings supporting the interpretation that direct cellular toxicity rather than stasis anoxia represented the mechanism of kidney injury by contrast media Direct immediate injury to vascular endothelium has been produced by perfusions of large quantities of contrast media through vessels of small animals (1, 44, 46, 65) but the doses used are so large that it is difficult to apply these observations to clinical angiography Thrombosis, the expected complication of severe injury to endothelium, is not a common feature of contrast medium reactions

There is a growing body of literature, however, favoring the concept that the adverse effects of contrast media are of anoxic ischemic character, secondary to action of these media on the blood plasma and its formed blood elements Foremost among the toxic manifestations has been a transient

VASOPRESSOR SHUNT

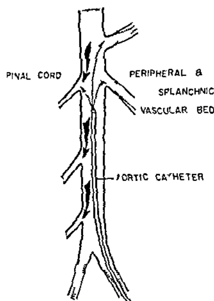


Fig 9 Schematic representation of the redistribution of blood flow produced by vasoactive agents as a result of the differential reactivity of the vascular beds of the somatic organs and those of the nervous system A vasopressor drug produces an increased vascular resistance in the somatic vascular bed diverting an otherwise innocuous intra aortic injection mass toward the vascular bed of the spinal cord hence augmenting its neurotoxic potential An approximately 10 to 20 fold difference in toxicity of roentgen contrast agents has been demonstrated between the two extremes of modifying influences of vasoactive drugs in the canine aortography model In view of the fact that the major changes in vascular tonus occur far distal to the depicted vascular beds this diagram errs on the side of simplicity in order to allow a presentation of the basis of redistribution of blood flow In actuality the order of vessels illustrated by this diagram may exhibit changes in caliber in an opposing direction i e an increase in lumen diameter may occur in the face of peripheral vasoconstriction

phase of severe sludging (3 4 5 21 28 29 55) associated with acute pulmonary congestion edema and hemorrhage a disturbance of cardiac rhythm and observable microcirculatory changes explicable on the basis of temporary vascular obstruction (2 3 4 5 19) These observations have gained in importance with the demonstration that antisludging agents exert a protective *action* against large intravenous doses of contrast agents (3, 4 5 54) and to a lesser degree against smaller intra aortic doses (54) An increased resistance to blood flow *in the* limbs produced by intra arterial injection of a contrast agent has been linked with *the presence* of *red blood* cells in the perfusate (50) Further, renal damage from an intra arterial contrast agent has been prevented by eliminating red cells *from the renal* perfusate (12) Hypertonicity with the production of extra cellular hyperosmolarity, has been considered to be the cause of both the immediate and the delayed toxic effects of contrast agents particularly after large doses (16 17 48 49) Certain contrast agents bind plasma albumin (30 31)) suggesting that protein binding may *constitute* an important mechanism of injury The studies of KUTT McDOWELL and associates (28 29 45) demonstrating (1) a reversible *aggregation* of protein molecules leading to alteration in electrophoretic mobility of blood proteins and lipoproteins

VASODEPRESSOR SHUNT

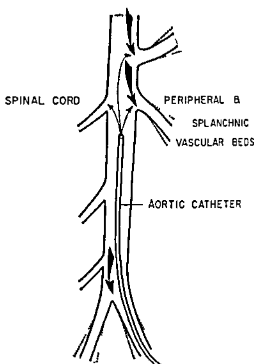


Fig 8 Schematic representation of the redistribution of blood flow produced by vasoactive agents as a result of the differential reactivity of the vascular beds of the somatic organs and those of the nervous system Vasodepressor drugs produce a decreased vascular resistance in the somatic vascular bed diverting a potentially neurotoxic intra aortic injection mass to the periphery hence reducing it below noxious levels in the vascular bed of the spinal cord This protective shunt has been induced by pharmacologic agents with diverse actions including local analgesics a ganglionic blocking drug and a smooth muscle relaxant In view of the fact that the major changes in vascular tonus occur far distal to the depicted vascular beds this diagram errs on the side of simplicity in order to allow a presentation of blood flow In actuality the order of vessels illustrated by this diagram may exhibit changes in caliber in an opposing direction i e a decrease in lumen diameter may occur in the face of peripheral vasodilatation

Our studies present overwhelming evidence of a primary, concentration dependent, immediate, vasotoxic effect of contrast agents This evidence is in agreement with earlier observations of BROMAN et coll (10, 8) that concentration was a major factor in the noxious action of these substances These workers observed that an agent of high concentration remaining in the cerebrovascular bed for but 1 second was more injurious than more dilute agents remaining in the vessels 10 to 70 seconds KILLEN & OWENS (26), measuring renal oxygen availability after Urokon perfusion obtained findings supporting the interpretation that direct cellular toxicity rather than stasis anoxia represented the mechanism of kidney injury by contrast media Direct immediate injury to vascular endothelium has been produced by perfusions of large quantities of contrast media through vessels of small animals (1, 44, 46, 65) but the doses used are so large that it is difficult to apply these observations to clinical angiography Thrombosis, the expected complication of severe injury to endothelium, is not a common feature of contrast medium reactions

There is a growing body of literature, however, favoring the concept that the adverse effects of contrast media are of anoxic ischemic character, secondary to action of these media on the blood plasma and its formed blood elements Foremost among the toxic manifestations has been a transient

towards greater safety particularly in pediatric angiology where the factor of dosage may constitute the principal hazard If, as has been experimentally demonstrated intrinsic vascular tonus is the major factor in the production of concentration dependent neurotoxic action an approach is available towards the protection of the central nervous system from injury in aortography and angiocardiography Considering that (1) it is in these procedures that the highest relative incidence of serious clinical complications have been encountered and (2) these injuries have commonly involved the spinal cord (25) brain stem and cerebrum regions outside the target zone of these procedures the potential value of this information is clearly evident In the literature on diagnostic angiology frequent reference is made to the hazards of angiography to organs which have a pre existing vascular disease (52) Our studies emphasize the alternate possibility namely that in the absence of overt brain disease the central nervous system may be imperiled by functional or anatomical vascular shunts resulting from the conditions leading to the need for diagnostic angiographic procedures For example this possibility can readily be envisaged in hypertension where there is a sustained elevation in systemic vascular tonus in occlusive aortic atherosclerosis where there is a strong collateral circulation via the important lumbar spinal radicles and in coarctation of the aorta with its multiple major collateral routes including the spinal branches of the intercostal arteries These speculations are given reality by two reported instances of unilateral renal damage occurring from aortography of patients with hypertension secondary to unilateral renal vascular disease (43 50) In both of these cases the better functioning kidney was severely injured and the kidney with decreased function was protected presumably because of its decreased blood flow After these considerations it may be pertinent to ask whether the evidence should be re examined that in the presence of cerebrovascular disease there are truly greater hazards to the central nervous system from four vessel angiography a procedure which is atraumatic for the carotid vertebral system To be specific will cranial vascular stenosis render the brain less rather than more vulnerable to injury in angiography? To explore the questions raised by the observations recorded herein studies are being set up in our laboratories investigating the effectiveness of long acting pharmacologic agents and the influence of vascular shunts in modifying neurotoxic effects of contrast agents in the canine aortography model If as postulated two mechanisms of injury exist therapy effective against one may be ineffective against the other Low molecular weight Dextran valuable as it is in combating systemic microcirculatory changes produced by contrast agents may have little influence upon a concentration dependent toxic action Conversely there is no theoretical basis on which to expect a vascular shunting action to protect from dose

(2) depression of free Ca and Mg levels leading to tetanic seizures and to disturbances of blood coagulation, (3) red cell aggregation and changes in vasomotion, *point to important mechanisms in* the production of contrast medium reactions via action on the blood and its formed elements, particularly when large doses of these agents are used.

To explain and to reconcile these conflicting sets of observations a unifying concept of the pathogenesis of contrast agent injury is proposed, namely, that there are two major mechanisms of injury. One is primary chemotoxic action exerted upon the vascular wall and parenchyma, the other is an ischemic hypoxic effect *secondary to obstruction of the microcirculation*. The primary toxic action is instantaneous in onset, and is concentration dependent. The secondary injury is predominantly dose dependent, and results from mass action upon the plasma and formed blood elements, with resultant microcirculatory disturbances leading to tissue anoxia. In any example of injury both mechanisms may participate, with one or the other playing the dominant role in production of damage.

The canine aortography model is presented as an experimental preparation providing a prime opportunity to study the pathogenesis of concentration dependent neurotoxic action of contrast agents. It is clearly evident from observations with this model, that the direction of shunting of an intra-aortic injection mass, rather than quantity or initial concentration of the medium, is *the major determinant of injury*. The *experimental studies* of BERNSTEIN & EVANS (3, 4, 5) focused upon acute cardiopulmonary effects of large intravenous doses of contrast agents represent a typical dose dependent model of injury, mediated through hypoxic ischemic sequelae of intravascular sludging. Consistent with this interpretation is the protective action exerted by the *antisludging agent, low molecular weight* Dextran, *upon this* latter model. Similarly, KUTT and associates (28, 29, 45), utilizing large quantities of contrast agents to explore effects upon blood protein, electrolytes and coagulation factors, make use of a dose dependent model. The studies of DEAN and associates (12), linking the presence of red cells in the renal vascular bed to vulnerability *to toxic effects of a large dose (1 ml/kg) of 70 % Urokon* argue against the concept advanced by the authors, but their experiments are complicated by their method of preparation of the target organ, namely the rapid injection of a massive quantity of perfusate (250 ml of 0.9 % saline in 90 sec) through an isolated aorticorenal segment.

Certain implications of importance to diagnostic angiology emerge from these studies. The development of a unified concept of contrast medium injury, allowing the delineation of dose dependent and concentration dependent toxic actions would greatly enhance the planning of angiographic procedures

towards greater safety, particularly in pediatric angiology where the factor of dosage may constitute the principal hazard If, as has been experimentally demonstrated intrinsic vascular tonus is the major factor in the production of concentration dependent neurotoxic action an approach is available towards the protection of the central nervous system from injury in aortography and angiocardiography Considering that (1) it is in these procedures that the highest relative incidence of serious clinical complications have been encountered, and (2) these injuries have commonly involved the spinal cord (25), brain stem and cerebrum regions outside the target zone of these procedures the potential value of this information is clearly evident In the literature on diagnostic angiology frequent reference is made to the hazards of angiography to organs which have a pre existing vascular disease (52) Our studies emphasize the alternate possibility, namely that in the absence of overt brain disease the central nervous system may be imperiled by functional or anatomical vascular shunts resulting from the conditions leading to the need for diagnostic angiographic procedures For example this possibility can readily be envisaged in hypertension where there is a sustained elevation in systemic vascular tonus, in occlusive aortic atherosclerosis where there is a strong collateral circulation via the important lumbar spinal radicles, and in coarctation of the aorta with its multiple major collateral routes including the spinal branches of the intercostal arteries These speculations are given reality by two reported instances of unilateral renal damage occurring from aortography of patients with hypertension secondary to unilateral renal vascular disease (43, 50) In both of these cases the better functioning kidney was severely injured and the kidney with decreased function was protected presumably because of its decreased blood flow After these considerations it may be pertinent to ask whether the evidence should be re examined that in the presence of cerebrovascular disease there are truly greater hazards to the central nervous system from four vessel angiography a procedure which is atraumatic for the carotid vertebral system To be specific will cranial vascular stenosis render the brain less rather than more vulnerable to injury in angiography? To explore the questions raised by the observations recorded herein studies are being set up in our laboratories investigating the effectiveness of long acting pharmacologic agents and the influence of vascular shunts in modifying neurotoxic effects of contrast agents in the canine aortography model If as postulated two mechanisms of injury exist therapy effective against one may be ineffective against the other Low molecular weight Dextran valuable as it is in combating systemic micro circulatory changes produced by contrast agents may have little influence upon a concentration dependent toxic action Conversely there is no theoretical basis on which to expect a vascular shunting action to protect from dose

dependent systemic toxic effects of contrast agents. Tests of these latter questions are now under way in our laboratories.

The revival of the idea (1), originally advanced by BROMAN & OLSSON (8) that alterations in permeability of the blood-brain barrier caused by contrast media might be exploited to increase the passage of therapeutic drugs into the brain causes some concern. When this consideration was first proposed, the neurotoxic potential of contrast media had not been fully appreciated. Observations that even the newer contrast media are capable of severe destructive action, and that the transition between non-toxic and severely toxic doses of these agents is extremely abrupt, indicate that there is no clearly definable middle ground of relative safety within which borderline toxic action upon the cerebral vascular bed might be induced to provide a therapeutic advantage. Although appearing to be rather straightforward in our earlier experiments, the relationship between permeability changes and severity of vasotoxic action is clearly more complex than originally conceived. For example, Levophed, which potentiated the neurotoxic action of contrast agents, blocked convulsive response not suppressable by deep pentobarbital or fluothane anesthesia. The Levophed block may be explained on the basis of its depressant action upon the central nervous system (33, 34, 53). On the other hand, Papaverine and Arfonad, while offering strong protection from neurotoxic effect, demonstrated no ameliorating influence upon the convulsive response (64). On the basis of this observation attribution of the convulsive response to the direct irritative action of a contrast agent at the neuronal level consequent to damage of the blood-brain barrier appears to be an oversimplified concept. In any event, a violent convulsive reaction does not always presage a necrotizing effect, nor does the lack of this discharge predicate the absence of toxic anatomic sequelae. Although changes in the blood-brain barrier produced by contrast media have been demonstrated to be reversible (7, 9, 14, 15, 58, 59), correlative pathologic studies must be done to exclude the absence of irreversible anatomic effects in such experiments. In any event, at our present state of knowledge, the use of contrast agents for the purpose of increasing the passage of therapeutic drugs into the brain is not justified.

Acknowledgements

This work was supported by U.S.P.H.S. grants NB 02266, NB 05160 and FR 5392. The technical assistance of S. M. Bourne and H. Page is gratefully acknowledged. All or part of the pharmaceutical preparations used in this study were provided by Mallinckrodt Pharmaceuticals, St. Louis, Missouri and Winthrop Laboratories, New York, New York.

SUMMARY

A vasopressor strongly potentiates and vasodepressors strikingly protect from neurotoxic effects of contrast media in an experimental aortography model. Dominance of somatic over neural vascular beds resulting in shunting explains these modifying influences. From these observations two mechanisms of injury are postulated: primary concentration dependent chemotoxic action upon tissue and dose dependent hypoxic ischemic effects secondary to microcirculatory obstruction. Of these effects only the former is considered amenable to action of vasoactive agents.

ZUSAMMENFASSUNG

Die neurotoxischen Wirkungen von Kontrastmitteln im experimentellen aortographischen Modellversuch werden von Vasopressoren potenziert, von Vasodepressoren hingegen verhindert. Die Erklärung dafür ist im Überwiegen der somatischen über die neuralen Gefässabschnitte — mit dem Resultat von Gefässkurzschlüssen — zu suchen. Als Folge dieser Beobachtung kann man bei einer Schädigung zwei Mechanismen annehmen: Primäre konzentrationsbedingte chemotoxische Gewebswirkung und dosisbedingte hypoxämische Wirkung als Folge von Unterbrechung der Mikrozirkulation. Von diesen Reaktionen ist nur die erste für die Wirkung von vasoaktiven Stoffen als verantwortlich anzusehen.

RÉSUMÉ

Dans une expérimentation aortographique les vasopresseurs potentialisent fortement et les vasodépresseurs empêchent de façon très nette les effets neurotoxiques des moyens de contraste. La dominance des réseaux vasculaires somatiques sur les réseaux vasculaires neuraux donnant lieu à un shuntage explique ces influences modificatrices. Ces observations font supposer deux mécanismes lésionnels: l'un dépendant de la concentration est l'action chimiotoxique sur les tissus, l'autre dépendant de la dose est l'effet hypoxique ischémique dû à l'obstruction microcirculatoire. De ces effets seul le premier est considéré comme sensible à l'action des agents vasoactifs.

REFERENCES

1. AUSMAN J I, YOUNG R and OWENS G. Radiopaque dyes and other agents in the production of endothelial damage. J surg Res 4 (1964) 349
2. AUSTEN W F, WILCOX B R and BENDER H W. Experimental studies of the cardiovascular responses secondary to the injection of angiographic agents. J thorac cardiovasc Surg 47 (1964) 283
3. BERNSTEIN E F and EVANS R L. The protective action of low molecular weight dextran upon intravenous hypaque toxicity. Surg Forum 11 (1960) 141
4. — — Low molecular weight dextran. J Amer med Ass 174 (1960) 417
5. — PALMER J D, AABERG T A and DAVIS R L. Studies of the toxicity of hypaque — 90 per cent following rapid intravenous injection. Radiology 76 (1961) 88
6. BLOOR B M, WRENN F R JR and MARGOLIS G. Effect of intracarotid iodopyracet (diodrast) upon cerebral blood flow. Arch Neurol Psychiat (Chic) 71 (1954) 348

dependent systemic toxic effects of contrast agents Tests of these latter questions are now under way in our laboratories

The revival of the idea (1), originally advanced by BROMAN & OLSSON (8) that alterations in permeability of the blood brain barrier caused by contrast media might be exploited to increase the passage of therapeutic drugs into the brain causes some concern When this consideration was first proposed, the neurotoxic potential of contrast media had not been fully appreciated Observations that even the newer contrast media are capable of severe destructive action, and that the transition between non toxic and severely toxic doses of these agents is extremely abrupt, indicate that there is no clearly definable middle ground of relative safety within which borderline toxic action upon the cerebral vascular bed might be induced to provide a therapeutic advantage Although appearing to be rather straightforward in our earlier experiments, the relationship between permeability changes and severity of vasotoxic action is clearly more complex than originally conceived For example, Levophed, which potentiated the neurotoxic action of contrast agents blocked convulsive response not suppressable by deep pentobarbital or fluothane anesthesia The Levophed block may be explained on the basis of its depressant action upon the central nervous system (33, 34, 53) On the other hand, Papaverine and Arfonad, while offering strong protection from neurotoxic effect, demonstrated no ameliorating influence upon the convulsive response (64) On the basis of this observation attribution of the convulsive response to the direct irritative action of a contrast agent at the neuronal level consequent to damage of the blood brain barrier appears to be an oversimplified concept In any event, a violent convulsive reaction does not always presage a necrotizing effect nor does the lack of this discharge predicate the absence of toxic anatomic sequelae Although changes in the blood brain barrier produced by contrast media have been demonstrated to be reversible (7, 9 14, 15, 58, 59) correlative pathologic studies must be done to exclude the absence of irreversible anatomic effects in such experiments In any event, at our present state of knowledge, the use of contrast agents for the purpose of increasing the passage of therapeutic drugs into the brain is not justified

Acknowledgements

This work was supported by U S P H S grants N B 02266 N B 05160 and FR 5392 The technical assistance of S M Bourre and H Page is gratefully acknowledged All or part of the pharmaceutical preparations used in this study were provided by Mallinckrodt Pharmaceuticals St Louis Missouri and Winthrop Laboratories New York New York

SUMMARY

A vasopressor strongly potentiates and vasodepressors strikingly protect from neurotoxic effects of contrast media in an experimental aortography model Dominance of somatic over neural vascular beds resulting in shunting explains these modifying influences From these observations two mechanisms of injury are postulated primary concentration dependent chemotoxic action upon tissue and dose dependent hypoxic ischemic effects secondary to microcirculatory obstruction Of these effects only the former is considered amenable to action of vasoactive agents

ZUSAMMENFASSUNG

Die neurotoxischen Wirkungen von Kontrastmitteln im experimentellen aortographischen Modellversuch werden von Vasopressoren potenziert von Vasodepressoren hingegen verhindert Die Erklarung dafur ist im Überwiegen der somatischen uber die neuralen Gefässabschnitte — mit den Resultat von Gefasskurzschlussen — zu suchen Als Folge dieser Beobachtung kann man bei einer Schadigung zwei Mechanismen annehmen Primare konzentrations bedingte chemotoxische Gewebswirkung und dosisbedingte hypoxamische Wirkung als Folge von Unterbrechung der Mikrozirkulation Von diesen Reaktionen ist nur die erste fur die Wirkung von vasoaktiven Stoffen als verantwortlich anzusehen

RÉSUMÉ

Dans une expérimentation aortographique les vasopresseurs potentialisent fortement et les vasodépresseurs empechent de façon très nette les effets neurotoxiques des moyens de contraste La dominance des réseaux vasculaires somatiques sur les réseaux vasculaires neuraux donnant lieu a un shuntage explique ces influences modificatrices Ces observations font supposer deux mécanismes lésionnels l un dépendant de la concentration est l action chimiotoxique sur les tissus l autre dépendant de la dose est l effet hypoxique ischémique du à l obstruction microcirculatoire De ces effets seul le premier est considéré comme sensible à l action des agents vasoactifs

REFERENCES

1 ALSMAN J I YOUNG R and OWENS G Radiopaque dyes and other agents in the production of endothelial damage J surg Res 4 (1964) 349

2 AUSTEN W E WILCOX B R and BENDER H W Experimental studies of the cardiovascular responses secondary to the injection of angiographic agents J thorac cardiovasc Surg 47 (1964) 283

3 BERNSTEIN E F and EVANS R L The protective action of low molecular weight dextran upon intravenous hypaque toxicity Surg Forum 11 (1960) 141

4 — — Low molecular weight dextran J Amer med Ass 174 (1960) 417

5 — PALMER J D AABERG T A and DAVIS R L Studies of the toxicity of hypaque — 90 per cent following rapid intravenous injection Radiology 76 (1961) 88

6 BLOOR B M WRENN F R JR and MARGOLIS G Effect of intracarotid iodopyracet (diodrast) upon cerebral blood flow Arch Neurol Psychiat (Chic) 71 (1954) 348

dependent systemic toxic effects of contrast agents Tests of these latter questions are now under way in our laboratories

The revival of the idea (1), originally advanced by BROMAN & OLSSON (8) that alterations in permeability of the blood brain barrier caused by contrast media might be exploited to increase the passage of therapeutic drugs into the brain causes some concern When this consideration was first proposed, the neurotoxic potential of contrast media had not been fully appreciated Observations that even the newer contrast media are capable of severe destructive action, and that the transition between non toxic and severely toxic doses of these agents is extremely abrupt, indicate that there is no clearly definable middle ground of relative safety within which borderline toxic action upon the cerebral vascular bed might be induced to provide a therapeutic advantage Although appearing to be rather straightforward in our earlier experiments, the relationship between permeability changes and severity of vasotoxic action is clearly more complex than originally conceived For example, Levophed, which potentiated the neurotoxic action of contrast agents, blocked convulsive response not suppressable by deep pentobarbital or fluothane anesthesia The Levophed block may be explained on the basis of its depressant action upon the central nervous system (33, 34, 53) On the other hand, Papaverine and Arfonad, while offering strong protection from neurotoxic effect, demonstrated no ameliorating influence upon the convulsive response (64) On the basis of this observation attribution of the convulsive response to the direct irritative action of a contrast agent at the neuronal level consequent to damage of the blood brain barrier appears to be an oversimplified concept In any event, a violent convulsive reaction does not always presage a necrotizing effect, nor does the lack of this discharge predicate the absence of toxic anatomic sequelae Although changes in the blood brain barrier produced by contrast media have been demonstrated to be reversible (7, 9, 14, 15, 58, 59), correlative pathologic studies must be done to exclude the absence of irreversible anatomic effects in such experiments In any event, at our present state of knowledge, the use of contrast agents for the purpose of increasing the passage of therapeutic drugs into the brain is not justified

Acknowledgements

This work was supported by U S P H S grants N B 02266 N B 05160 and FR 5392 The technical assistance of S M Bourre and H Page is gratefully acknowledged All or part of the pharmaceutical preparations used in this study were provided by Mallinckrodt Pharmaceuticals St Louis Missouri and Winthrop Laboratories New York New York

28 — MILHORAT T H and McDOWELL F The effect of iodinized contrast media upon blood proteins electrolytes and red cells Neurology 13 (1963) 492
29 KUTT H and McDOWELL F Effects of iodinized contrast media upon electrophoretic mobilities of blood proteins and lipoproteins J Lab and Clin Med 59 (1962) 118
30 LASSER E C ELIZONDO MARTEL G and GRANKE R C Potentiation of pentobarbital anesthesia by competitive protein binding Anesthesiology 24 (1963) 665
31 — — — The roentgen contrast media potentiation of nembutal anesthesia in rats Amer J Roentgenol 91 (1964) 453
32 LAZORTHES G Vascularisation et circulation cerebrales Masson & Cie Paris 1961
33 LEIMDORFER A Analgesia and anesthesia induced by epinephrine Amer J Physiol 157 (1949) 116
34 — The action of sympathomimetic amines on the central nervous system and the blood sugar Relation of chemical structure to mechanism of action J Pharmacol exp Ther 98 (1950) 62
35 LINDGREN P and TORNELL G Blood circulation during and after peripheral arteriography Experimental study of the effects of triurol (sodium acetrizoate) and hypaque sodium diatrizoate) Acta radiol 49 (1958) 425
36 — Blood pressure and heart rate responses in carotid angiography with sodium acetrizoate (triurol) An experimental study in cats Acta radiol 50 (1958) 160
37 — NORDENSTROM B and TORNELL G Arterial spasm treated with sodium acetrizoate Acta chir scand Suppl 245 (1959) 351
38 MARGOLIS G The effect of various agents on the toxic action of contrast media Fourth Princeton Conference on Cerebrovascular Disease January 1964
39 — TARAZI A K and GRIMSON K S Contrast medium injury to the spinal cord produced by aortography Pathologic anatomy of the experimental lesion J Neurosurg 13 1956) 349
40 — et coll Evaluation of roentgen contrast agents used in cerebral arteriography I A simple screening method J Neurosurg 15 (1958) 30
41 — et coll Circulatory dynamics of the canine spinal cord Temporal phases of blood flow measured by fluorescein and serioroentgenographic methods J Neurosurg 14 (1957) 506
42 — et coll Contrast medium injury to the spinal cord Role of altered circulatory dynamics J Neurosurg 16 (1959) 390
43 McCALLISTER B D HUNT J C and KINCAID O W Unilateral renal atrophy subsequent to renal arteriography Proc Mayo Clin 37 (1962) 323
44 McCONNELL F and MERSEREAU W A The effect of angiographic contrast media on arterial endothelium — an experimental study J Canad Ass Radiol 15 (1964) 14
45 McDOWELL F and BANG N U Discussion on complications of angiography Fourth Princeton Conference on Cerebrovascular Disease January 1964
46 MERSEREAU W A and ROBERTSON H R Observations on venous endothelial injury following the injection of various radiographic contrast media in the rat J Neurosurg 18 (1961) 289
47 RAYNOR R B and ROSS G Arteriography and vasospasm The effects of intracarotid contrast media on vasospasm J Neurosurg 17 (1960) 1055
48 READ R C Cause of death in cardioangiography J thorac cardiovasc Surg 38 (1959) 685
49 — JOHNSON J A VICK J A and MEYER M W Vascular effects of hypertonic solutions Circulat Res 8 (1960) 538

7 BROMAN T and OLSSON O The tolerance of cerebral blood vessels to a contrast medium of the diodrast group an experimental study of the effect on the blood brain barrier Acta radiol 30 (1948) 326

8 — — Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels Acta radiol 31 (1949) 321

9 — — Technique for the pharmaco dynamic investigation of contrast media for cerebral angiography Effect on the blood brain barrier in animal experiments Acta radiol 45 (1956) 96

10 — FORSSMAN B and OLSSON O Further experimental investigations of injuries from contrast media in cerebral angiography summation of various injurious factors Acta radiol 34 (1950) 135

11 CANOSSI G BRUNELLI B CORTESI N and CARPI A Rapid serial angiography in the investigation of the pharmacology of brain circulation in the dog Circulat Res 10 (1962) 259

12 DEAN R E ANDREWS J H and READ R C The red cell factor in renal damage from angiographic media J Amer med Ass 187 (1964) 27

13 FOLTZ E L THOMAS L B and WARD A A JR The effects of intracarotid diodrast J Neurosurg 9 (1952) 68

14 FLODMARK S and STEINWALL O A method for study of the interrelation between EEG and blood brain barrier phenomena Acta physiol scand 56 (1962) 112

15 — — Reversible blood brain barrier alteration induced by certain organic acids and indicated by means of EEG and dye tests Acta physiol scand 58 (1963) 368

16 GARBER G L and READ R C Protective effect of hypervolemia in cardioangiography J Amer med Ass 180 (1962) 376

17 GIAMMONA S T LURIE P R and SEGAR W E Hypertonicity following selective angio cardiography Circulation 28 (1963) 1096

18 HOL R and SKJERVEN O Spinal cord damage in abdominal aortography Acta radiol 42 (1954) 276

19 HOEPPE J O Some pharmacological aspects of radiopaque compounds Ann N Y Acad Sci 78 (1959) 727

20 INGVAR D H and SODERBERG U Cerebral vasomotor tone and EEG during injection of umbradil An experimental study with a new method Acta radiol 47 (1957) 185

21 JOHNSON J H and KNISELY M H Intravascular agglutination of the flowing blood following the injection of radiopaque contrast media Neurology 12 (1962) 560

22 KÅGSTROM E LINDGREN P and TORNELL G Changes in cerebral circulation during carotid angiography with sodium acetrizoate (triurol) and sodium diatrizoate (Hypaque) Acta radiol 50 (1958) 151

23 — — — Circulatory disturbances during cerebral angiography An experimental evaluation of certain contrast media Acta radiol 54 (1960) 3

24 KERNAN P D TINDALL G T MARGOLIS G and WOOD R S The prevention of experimental contrast medium injury to the nervous system J Neurosurg 15 (1958) 92

25 KILLEN D A and FOSTER J H Spinal cord injury as a complication of aortography Ann Surg 152 (1960) 211

26 — and LANCE E M Investigation of means to prevent spinal cord and renal damage incident to urokon aortography Surgery 51 (1962) 338

27 — and OWENS G Changes of renal oxygen availability during Urokon and Hypaque aortography Ann Surg 152 (1960) 957

FROM THE HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA DEPARTMENT OF RADIOLOGY PHILADELPHIA U S A

PETECHIAL REACTIONS IN ANGIOGRAPHY

by

MARK M MISHKIN

During a routine follow up of patients following cerebral angiography extensive petechial hemorrhages were demonstrated in the distribution of the external carotid artery in two patients on the same day

More careful examination of two other patients investigated with carotid angiography the same day revealed petechial hemorrhages of a much milder degree Following this initial observation careful examination of every patient undergoing angiography carotid or otherwise was performed This report is concerned with the incidence of this complication and one of its probable mechanisms

Many complications secondary to cerebral angiography have been described in the literature but the local petechial reaction has received scant attention A review of the American literature since 1950 reveals 18 cases of petechial hemorrhages as a complication of angiography (ECKER 1951, UIHLEIN 1951 ABBOTT GAY & GOODALL 1952 DUNN UIHLEIN & HOLMAN 1956, DE SAUSSURE & KEIRNS 1962 SPUDIS SCHARYJ ALEXANDER & MARTIN 1962 LANG 1963, DAROFF & MCENTEE 1964) Not included in these 18 are four cases reported by DAROFF & MCENTEE (1964) which are part of this present series ECKER (1951) has an illustration of a patient who underwent right cerebral angiography and had petechiae in the distribution of the right external carotid

50 SAAVEDRA J A ABBOT J P and NUNNALLY R M Unilateral malignant nephrosclerosis with superimposed unilateral cortical necrosis following an aortogram Amer J clin Path 35 (1961) 147
51 SCHMIDT H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media Acta radiol 44 (1955) 100
52 SCHFINBERG P and ZUNKER E Complications in direct percutaneous carotid arteriography Arch Neurol 8 (1963) 676
53 SCHWEITZER A and WRIGHT S Action of adrenaline on the knee jerk J Physiol 88 (1937) 476
54 SESSIONS R T KILLEN D A and FOSTER J H Low molecular weight dextran as a protective agent against the toxic effects of Urokon Amer Surg 28 (1962) 455
55 SOBIN S S FRASHER W G JACOBSON G and VAN EECKHOVEN E A Nature of adverse reactions to radiopaque agents J Amer med Ass 170 (1959) 1546
56 SAKO Y Hemodynamic changes during arteriography J Amer med Ass 183 (1963) 253
57 SOKOLOFF L Action of drugs on cerebral circulation Pharmacol Rev 11 (1959) 1
58 STEINWALL O An improved technique for testing the effect of contrast media and other substances on the blood brain barrier Acta radiol 49 (1958) 281
59 — Transport mechanisms in certain blood brain barrier phenomena — a hypothesis Acta psychiat Suppl 314 1961
60 TARAZI A K MARGOLIS G and GRIMSON K S Spinal cord lesions produced by aortography in dogs Arch Surg 72 (1956) 38
61 TINDALL G T and JACKSON J R Clinical evaluation of procaine and hypertonic glucose as possible adjuncts of carotid arteriography J Neurosurg 17 (1960) 43
62 — et coll Evaluation of roentgen contrast agents used in cerebral arteriography II Application of a new method J Neurosurg 15 (1958) 37
63 WIEDEMAN M P Distribution and sizes of vessels and their responses to intra arterial injections of radiopaque materials Bibl Acta (Suppl Acta Anat) 4 (1964) 756
64 YERASIMIDES T G MARGOLIS G and PONTON H J Prophylaxis of experimental contrast medium injury to the spinal cord by vasodepressor drugs Angiology 14 (1963) 394
65 ZINNER G and COTTLOB R Morphologic changes in vessel endothelia caused by contrast media Angiology 10 (1959) 207

FROM THE HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA, DEPARTMENT OF RADIOLOGY PHILADELPHIA U S A

PETECHIAL REACTIONS IN ANGIOGRAPHY

by

MARK M MISHKIN

During a routine follow up of patients following cerebral angiography, extensive petechial hemorrhages were demonstrated in the distribution of the external carotid artery in two patients on the same day

More careful examination of two other patients investigated with carotid angiography the same day revealed petechial hemorrhages of a much milder degree Following this initial observation careful examination of every patient undergoing angiography carotid or otherwise was performed This report is concerned with the incidence of this complication and one of its probable mechanisms

Many complications secondary to cerebral angiography have been described in the literature but the local petechial reaction has received scant attention A review of the American literature since 1950 reveals 18 cases of petechial hemorrhages as a complication of angiography (ECKER 1951 UIHLEIN 1951 ABBOTT GAY & GOODALL 1952 DUNN UIHLEIN & HOLMAN 1956 DE SAUSSURE & KEIRNS 1962 SPUDIS SCHARYJ ALEXANDER & MARTIN 1962 LANG 1963, DAROFF & MCENTEE 1964) Not included in these 18 are four cases reported by DAROFF & MCENTEE (1964) which are part of this present series ECKER (1951) has an illustration of a patient who underwent right cerebral angiography and had petechiae in the distribution of the right external carotid

50 SAAVENDA J A , ABBOT J P and NUNNALLY R M Unilateral malignant nephrosclerosis with superimposed unilateral cortical necrosis following an aortogram Amer J clin Path 35 (1961), 147
51 SCHMIDT H W The behavior of the pial vessels during and after the intracarotid injection of roentgen contrast media *Acta radiol 44 (1955), 100*
52 SCHEINBERG P and ZUNKER E Complications in direct percutaneous carotid arteriography Arch Neurol 8 (1963) 676
53 SCHWEITZER A and WRIGHT S Action of adrenaline on the knee jerk J Physiol 88 (1937) 476
54 SESSIONS R T , KILLEN D A and FOSTER J H Low molecular weight dextran as a protective agent against the toxic effects of Urokon Amer Surg 28 (1962) 455
55 SOBIN S S FRASHER W G JACOBSON G and VAN FECKHOVEN I A Nature of adverse reactions to radiopaque agents J Amer med Ass 170 (1959) 1546
56 SAKO Y Hemodynamic changes during arteriography J Amer med Ass 183 (1963) 253
57 SOKOLOFF L Action of drugs on cerebral circulation Pharmacol Rev 11 (1959) 1
58 STEINWALL O An improved technique for testing the effect of contrast media and other substances on the blood brain barrier Acta radiol 49 (1958) 281
59 — *Transport mechanisms in certain blood brain barrier phenomena — a hypothesis* Acta psychiat Suppl 314 1961
60 TARAZI A K MARGOLIS G and GRIMSON K S Spinal cord lesions produced by aortography in dogs Arch Surg 72 (1956) 38
61 TINDALL C T and JACKSON J R Clinical evaluation of procaine and hypertonic glucose as possible adjuncts of carotid arteriography J Neurosurg *17 (1960) 43*
62 — et coll Evaluation of roentgen contrast agents used in cerebral arteriography II Application of a new method J Neurosurg 15 (1958) 37
63 WIEDEMAN M P Distribution and sizes of vessels and their responses to intra arterial injections of radiopaque materials Bibl Acta (Suppl Acta Anat) 4 (1964) 756
64 YERASIMIDES T G MARGOLIS G and PONTON H J Prophylaxis of experimental contrast medium injury to the spinal cord by vasodepressor drugs Angiology 14 (1963) 394
65 ZINNER G and GOTTLOB R Morphologic changes in vessel endothelia caused by contrast media Angiology 10 (1959) 207

FROM THE HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA DEPARTMENT OF RADIOLOGY, PHILADELPHIA U S A

PETECHIAL REACTIONS IN ANGIOGRAPHY

by

MARK M MISHKIN

During a routine follow up of patients following cerebral angiography extensive petechial hemorrhages were demonstrated in the distribution of the external carotid artery in two patients on the same day

More careful examination of two other patients investigated with carotid angiography the same day revealed petechial hemorrhages of a much milder degree Following this initial observation careful examination of every patient undergoing angiography carotid or otherwise, was performed This report is concerned with the incidence of this complication and one of its probable mechanisms

Many complications secondary to cerebral angiography have been described in the literature but the local petechial reaction has received scant attention A review of the American literature since 1950 reveals 18 cases of petechial hemorrhages as a complication of angiography (ECKER 1951 UIHLEIN 1951 ABBOTT GAY & GOODALL 1952 DUNN, UIHLEIN & HOLMAN 1956 DE SAUSSURE & KEIRNS 1962 SPUDIS SCHARYJ ALEXANDER & MARTIN 1962, LANG 1963 DAROFF & MCENTEE 1964) Not included in these 18 are four cases reported by DAROFF & MCENTEE (1964) which are part of this present series ECKER (1951) has an illustration of a patient who underwent right cerebral angiography and had petechiae in the distribution of the right external carotid



Fig 1 Case I Bilateral facial and conjunctival petechial hemorrhages six hours after bilateral carotid angiography Right side — selective internal carotid angiography left side — selective external and common carotid angiography Petechiae are prominent in distribution of right external carotid artery

artery and a transient left hemiplegia UHLEIN (1951) described two cases of extensive petechial hemorrhages in a series of 100 angiograms utilizing Diodrast as the contrast medium ABBOTT et coll (1952) found two cases of facial petechial hemorrhages in 174 angiograms and included in their report an additional case In this particular article the patients demonstrated conjunctival, scleral and retinal petechiae DUNN et coll (1956) found one case of petechial hemorrhage in 50 cerebral angiograms utilizing Hypaque DE SAUSSURE (1962) described three cases of petechial hemorrhages in 300 angiograms utilizing a retrograde catheter technique, with the catheter in the right common carotid artery SPUDIS et coll (1962) reported a case which came to postmortem examination while cutaneous petechiae were still present In this instance no cerebral petechiae were seen LANG (1963) shows a picture of extensive petechial hemorrhage following retrograde catheterization of the left subclavian artery and injection of Hypaque 50 % This is the only mention of petechial hemorrhages in his survey of complications of retrograde angiography encompassing 11 402 procedures Finally, DAROFF & MCENTEE (1964) describe



Fig 2 Case 2 Extensive right cutaneous petechiae over distribution of right external carotid artery Sharp midline cut off Patient also had a right visual scotoma

six cases of petechial reactions following cerebral angiography with Hypaque 50 % and mention four additional cases from the present series In none of the above reports was an etiologic mechanism demonstrated In one of DAROFF & McENTEE s cases a postmortem examination was obtained six days after the angiography and no cerebral petechiae were noted The cutaneous mucosal and conjunctival petechiae had presumably disappeared since they had started to fade four days prior to death The cause of death in this case was a ruptured aneurysm of the posterior communicating artery

Case reports

Case 1 A C A 58-year-old white male admitted with right hemiparesis right hemihypesthesia and involuntary movements of the right hand progressive for 11 months A bilateral cerebral angiography was performed utilizing the percutaneous catheterization technique as

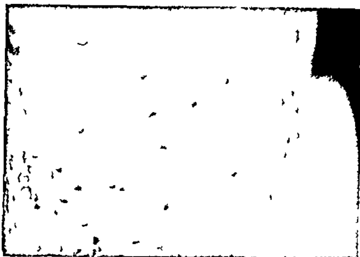


Fig 3 Case 4 A moderate number of petechial hemorrhages over distribution of left external carotid artery Close up view of the neck

described by Seldinger (1953) Following puncture of the right common carotid artery the catheter was placed in the right internal carotid artery Two injections of 7 ml Hypaque 50 % were made The attempt at selective catheterization of the right external carotid artery was unsuccessful Puncture and catheterization of the left common artery was then performed with the tip of the catheter in the left external carotid artery Two injections of 6 ml each of Hypaque 50 % were made Following this the catheter was withdrawn into the common carotid artery and 2 injections of 8 ml Hypaque were made A left parasagittal meningioma was found

Six hours after the angiography multiple petechiae were seen over the distribution of both external carotid arteries being more prominent on the right (Fig 1) These were entirely asymptomatic It should be noted that no contrast material had been injected into the right external carotid artery but only into the internal carotid artery yet there were decidedly more petechial hemorrhages on the right side of the face These hemorrhages began to fade spontaneously 48 hours after the examination and no residua were noted

Case 2 M A A 40 year old white female entered the hospital for investigation of a possible intracranial aneurysm or vascular malformation Percutaneous punctures of the left and right common carotid arteries were made (left side 2 injections of 8 ml Hypaque 50 % and 1 injection of 6 ml right side 2 injections of 8 ml Hypaque 50 % and 5 injections of 6 ml) The findings were normal

When seen approximately 5 hours after the examination many petechial hemorrhages of the face and neck in the distribution of the right external carotid artery were noted (Fig 2) In addition hemorrhages were present in the conjunctival sac and on the hard palate on the right The patient complained of a blank spot in her vision when she used her right eye and funduscopy revealed evidence of retinal hemorrhage A coagulogram was entirely normal

The petechial reaction began to fade spontaneously after approximately 24 hours and dis



Fig 4 Starch granules stained with PAS × 480

appeared in 3 days Over the ensuing 6 months the scotoma decreased in size but a repeat evaluation of the visual fields demonstrated a persistent small scotoma on the right

Case 3 H T A 41 year-old Negro male was admitted for evaluation of blackout spells Bilateral percutaneous carotid angiographies were performed and 8 ml Hypaque 50 % were injected twice into each carotid artery No abnormalities were seen on the films

Approximately 5 hours after this examination petechiae were seen bilaterally in the conjunctivae and faintly over the distribution of the external carotid arteries There were no subjective symptoms and the petechiae faded spontaneously over the next 3 days

Case 4 M G A 57 year old white female was admitted with a diagnosis of stenosis of the proximal left internal carotid artery and underwent percutaneous left carotid angiography Two injections of 8 ml Hypaque 50 % were made

Because of the findings in the three preceding cases the patient was seen 3 hours after angiography no petechial hemorrhages were noted She was revisited 14 hours after angiography and careful inspection demonstrated a moderate number of petechial hemorrhages on the left side of her face and neck (Fig 3) Although she had no subjective complaints a right homonymous hemianopsia and a slight right hemiparesis were noted these had not been present prior to angiography

Two days following the angiography the stenotic left carotid artery was repaired and her postoperative course was uneventful The hemiparesis cleared but the homonymous hemianopsia persisted

Table 1

Incidence of petechial hemorrhages

	No of patients	No of carotid angiographies	No of cases with petechiae	% of cases with petechiae
With gloves	115	191	45	38
Without gloves	125	219	5	4

Table 2

Comparison of contrast material and patients with and without petechial reactions

Contrast medium	Presence of petechiae	Average age Male/Female	No of injections of contrast medium per angiography	Total volume of contrast medium per angiography	Duration of needle in situ	No of patients
Hypaque 50 %	Yes	46.1/43.7	2.4	21.5 ml	42	14
Hypaque 50 %	No	42.1/41.6	2.9	22.9 ml	36.5	115
Conray	Yes	48.6/37.9	3.1	23.1 ml	31.5	27
Conray	No	47.4/47.7	2.9	23.3 ml	27	60
Renografin 60	Yes	44.5/43.3	2.8	24.5 ml	33	9
Renografin 60	No	47.5/48.7	3.4	27.2 ml	44	15

Investigation

Clinical As the four cases described above had occurred on the same day the entire angiographic procedure was reviewed the following day, and no change in the technique of preparing, cleaning, or sterilizing the instruments was elicited. Our own routine of angiography was carefully reviewed, and no breaks in technique could be detected. As the only other possible variable was the contrast medium utilized the entire remaining batch of material (Hypaque 50 %) was returned to the manufacturer for testing, the results of this analysis were entirely negative.

For empirical reasons it was decided to utilize other forms of contrast medium (Renografin 60, Conray, and in addition, in angiography of other areas of the body, Angio Conray and Cardiografin). At the same time detailed records were kept of each patient undergoing angiography, the patient being visited at least once four hours after the procedure.

Between March 1963 and September 1963, 172 carotid angiographies were performed in 105 patients, and follow up examinations demonstrated 38 patients with petechial hemorrhages. This yielded a 38 % incidence of



F g 5 M croscop c sect on of cat s brain showing four intravascular starch granules × 1?0

petechial hemorrhages among these patients Most of these were confined to the conjunctiva and palate, were mostly bilateral and if they had not been searched for would almost certainly have gone unnoticed An occasional case exhibited a moderate number of petechial hemorrhages but no patients in this series demonstrated the overwhelming reaction seen in cases 1 and 2 (Figs 1 and 2)

Because of the high incidence of petechial reactions a renewed search for an etiologic agent was made When it was noticed that minute particles of powder were floating on the surface of the isotonic saline solution used to irrigate the needle or catheter while it was *in situ* it was decided that wherever feasible the procedure would be done without the use of gloves but following a surgical scrub of the hands Since that time 219 carotid angiographies have been performed in 125 patients without the use of gloves In this group five patients demonstrated between one and five petechiae in the conjunctiva This yields an incidence of 4 % of the patients During this same period gloves were used in 19 angiographies on 10 patients and in 7 of these petechial reactions were seen The compared results are shown in Table 1

A detailed comparison was made of the contrast material used in patients

Table 1

Incidence of petechial hemorrhages

	No. of patients	No. of carotid angiographies	No. of cases with petechiae	% of cases with petechiae
With gloves	115	191	45	38
Without gloves	125	219	5	4

Table 2

Comparison of contrast material and patients with and without petechial reactions

Contrast medium	Presence of petechiae	Average age Male/Female	No. of injections of contrast medium per angiography	Total volume of contrast medium per angiography	Duration of needle in situ	No. of patients
Hypaque 50 %	Yes	46.1/43.7	2.4	21.5 ml	42	14
Hypaque 50 %	No	42.1/41.6	2.9	22.9 ml	36.5	115
Conray	Yes	48.6/37.9	3.1	23.1 ml	31.5	[illegible]7
Conray	No	47.4/47.7	2.9	23.3 ml	27	60
Renografin 60	Yes	44.5/43.3	2.8	24.5 ml	33	9
Renografin 60	No	47.5/48.7	3.4	27.2 ml	44	15

Investigation

Clinical. As the four cases described above had occurred on the same day the entire angiographic procedure was reviewed the following day, and no change in the technique of preparing, cleaning, or sterilizing the instruments was elicited. Our own routine of angiography was carefully reviewed, and no breaks in technique could be detected. As the only other possible variable was the contrast medium utilized the entire remaining batch of material (Hypaque 50 %) was returned to the manufacturer for testing, the results of this analysis were entirely negative.

For empirical reasons it was decided to utilize other forms of contrast medium (Renografin 60, Conray, and in addition, in angiography of other areas of the body, Angio Conray and Cardiografin). At the same time detailed records were kept of each patient undergoing angiography, the patient being visited at least once four hours after the procedure.

Between March 1963 and September 1963, 172 carotid angiographies were performed in 105 patients, and follow up examinations demonstrated 38 patients with petechial hemorrhages. This yielded a 38 % incidence of



Fig 5 Microscopic section of cat's brain showing four intravascular starch granules × 190

petechial hemorrhages among these patients Most of these were confined to the conjunctiva and palate were mostly bilateral and if they had not been searched for would almost certainly have gone unnoticed An occasional case exhibited a moderate number of petechial hemorrhages but no patients in this series demonstrated the overwhelming reaction seen in cases 1 and 2 (Figs 1 and 2)

Because of the high incidence of petechial reactions a renewed search for an etiologic agent was made When it was noticed that minute particles of powder were floating on the surface of the isotonic saline solution used to irrigate the needle or catheter while it was *in situ* it was decided that wherever feasible the procedure would be done without the use of gloves but following a surgical scrub of the hands Since that time 219 carotid angiographies have been performed in 125 patients without the use of gloves In this group five patients demonstrated between one and five petechiae in the conjunctiva This yields an incidence of 4 % of the patients During this same period gloves were used in 19 angiographies on 10 patients and in 7 of these petechial reactions were seen The compared results are shown in Table 1

A detailed comparison was made of the contrast material used in patients

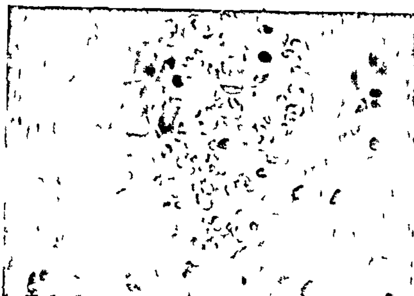


Fig 6 Microscopic section of cat's brain showing perivascular petechial hemorrhage 480

with and without petechiae as well as the age, sex, number of injections, total amount injected into each artery, and duration of examination No difference was noted between the two groups, except for the presence or absence of gloves and therefore of powder (Table 2) The probability of the observed difference being due to a random sampling error is appreciably less than five in one thousand (p 0 005)

During this same interval petechial hemorrhages were noted from time to time following aortographies and selective injections of major vessels arising from the aorta Since all of these studies were done utilizing catheters, gloves were used in each instance

Experimental In order to test the relationship between the particulate matter and petechial hemorrhages, saline containing some of the powder was injected into the carotid arteries of cats

The powder is a standard sterile material which is a reduced form of corn starch It consists of amylose and amylopectin and contains 2 % magnesium oxide as a filler The particles range in size from 0 5 to 40 microns with an average of 25 to 30 microns When introduced into the cavities of the body it is broken down enzymatically as a carbohydrate and absorbed in about seven days in the experimental animal It is completely insoluble in water, saline or blood

An attempt was made to equate the injections into the carotid artery of the cat with the equivalent injections into the human patients Some of the powder



Fig 7 Microscopic section of cat s brain showing occlusion of small arteriole by starch granule × 480

was sprinkled onto the surface of isotonic saline injected into the carotid artery of the cat and approximately two hours later the cat was sacrificed In one case the vessels on the surface of the brain were observed during the injection and it could be seen that during the injection of saline the blood filled vessels became transiently filled with saline and appeared as crystal clear tubes During the injection of saline containing the powder suspension instead of the vessels refilling with blood after two or three seconds several of the vessels were seen to remain filled with saline for a period up to 20 minutes

Fig 4 demonstrates a PAS stain of the starch granules and Fig 5 reveals a section of the cat s brain showing several of the granules lying within the blood vessels Fig 6 under higher magnification demonstrates a typical perivascular petechial hemorrhage and Fig 7 also under higher magnification demonstrates a starch particle within a small arteriole

Discussion

While these petechial reactions in the past have been characterized as benign and self limited (1964) this has not been our experience In case 2 of this report there must be a presumptive relationship between the angiography and the scotoma which accompanied the petechial reaction In case 4 it is uncertain whether the homonymous hemianopsia is related to the angiography It seems reasonable to assume however, that during injections of the common carotid artery the bulk of the injection goes into the internal carotid tree since approximately two thirds of the blood follows this path Any

particulate foreign matter would, statistically, be distributed likewise Although serious sequelae have not been reported previously, it is quite reasonable to assume that multiple minute infarctions can occur throughout the cerebral hemispheres without producing neurologic deficits It seems obvious, however, that any possible insult to the brain must be avoided From the experience at our institution there is a definite relationship between the occurrence of petechial hemorrhages and the use of powder on the gloves as demonstrated in the clinical material and in the experimental animal The obvious solution is to keep the powder out of the material to be injected This can be accomplished by *using an entirely closed system as advocated by* RING (personal communication) However, we have noticed a tendency on the part of angiographers wearing gloves to be less careful about not handling the tip or shaft *of the needle*, another source of possible contamination

The presence of the few petechial hemorrhages in the five patients in the series who were examined without gloves obviously cannot be explained on the basis of the powder If the starch derivative powder, acting as particulate material, can produce this reaction there is no reason why other particulate material cannot do the same SILBERMAN et coll (1960) have reported five cases of foreign body emboli due to cotton fibers being introduced during cerebral angiography CHASON et coll (1963) reported five other cases of cotton fiber embolism, in addition to two cases of cotton fiber implantation into the carotid artery directly during cerebral angiography COGAN et coll (1964) have reported fat emboli in the retina following angiography, this was explained on the basis of atheromata being introduced into the blood stream at the site of puncture of the carotid artery Either or both of these explanations may be involved in the five cases of petechial hemorrhages in our series in which gloves were not used

BROMAN & OLSSON (1948, 1949) have previously demonstrated the effects of Diodrast on cerebral blood vessels in the rabbit Using various concentrations of Diodrast injected over varying lengths of time, they demonstrated an increase in permeability of the cerebral vessels resulting in edemas, stasis, and punctate hemorrhages

Therefore, it must be assumed that there is more than one mechanism involved in the production of these petechiae, but certainly particulate material must be included as one of these mechanisms

Acknowledgements

I wish to express my appreciation to Dr Nicholas Gonatas and Dr Gabriel Schwarz of the Department of Neurology for their assistance with the microscopic sections and to Dr G Milton Shy and Dr Eli Goldensohn of the Department of Neurology for the use of their animal laboratory

SUMMARY

A discussion of the incidence and origin of petechial reactions associated with cerebral angiography is presented Clinical and laboratory evidence indicated that the powder used on surgically sterile gloves is one of the causative factors

ZUSAMMENFASSUNG

Das Auftreten und die Ursprung von petechialen Reaktionen im Zusammenhang mit cerebraler Angiographie wird besprochen Klinische Untersuchungen und Laboratorium untersuchungen haben ergeben dass das fur die kirurgischen sterilen Handschuhe verwendete Puder einer der ursachlichen Faktoren darstellt

RESUMÉ

L auteur étudie la fréquence et l origine de pétéchies en relation avec l angiographie cérébrale Les recherches cliniques et de laboratoire ont montré que la poudre utilisée sur les gants chirurgicaux stériles est une des causes de cet incident

REFERENCES

ABBOTT K H GAY J R and GOODALL R J Clinical complications of cerebral angiography J Neurosurg 9 (1952) 258

BROMAN T and OLSSON O The tolerance of cerebral blood vessels to a contrast medium of the Diodrast group An experimental study of the effect on the blood brain barrier Acta radiol 30 (1948) 326

— — Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels Acta radiol 31 (1949) 321

CHASON J L LANDERS J W and SWANSON R E Cotton fiber embolism a frequent complication of cerebral angiography Neurology 13 (1963) 558

COGAN C G KUWABARA T and MOSER H Fat emboli in retina following angiography Arch Ophthal 71 (1964) 308

DAROFF R B and McENTEE W J Local petechial reactions following cerebral angiography with Hypaque J Neurosurg 21 (1964) 381

DESAUSSURE R L and KEIRNS M M Retrograde carotid catheterization for arteriography J Neurosurg 19 (1962) 207

DUNN J JR UIHLEIN A and HOLMAN C B The use of sodium diacetrizoate in cerebral angiography J Neurosurg 13 (1956) 677

ECKER A The normal cerebral angiogram First edition Charles C Thomas Springfield Ill 1951

LANG E K Complications of retrograde percutaneous arteriography J Urol 90 (1963) 604

RING A J Personal communication

SELDINGER S I Catheter replacement of the needle in percutaneous arteriography A new technique Acta radiol 39 (1953) 368

SILBERMAN J CRAVIOTO H and FEIGEN I Foreign body emboli following cerebral angiography Arch Neurol 3 (1960) 711

SPUDIS E V SCHARYJ M ALEXANDER E and MARTIN J F Dissecting aneurysms in the head and neck Neurology 12 (1962) 867

UIHLEIN A Cerebral angiography Proc Mayo Clin 26 (1951) 133

particulate foreign matter would, statistically, be distributed likewise Although serious sequelae have not been reported previously, it is quite reasonable to assume that multiple minute infarctions can occur throughout the cerebral hemispheres without producing neurologic deficits It seems obvious, however, that any possible insult to the brain must be avoided From the experience at our institution there is a definite relationship between the occurrence of petechial hemorrhages and the use of powder on the gloves as demonstrated in the clinical material and in the experimental animal The obvious solution *is to keep the powder out of the material to be injected* This can be accomplished by using an entirely closed system as advocated by RIXE (personal communication) However, we have noticed a tendency on the part of angiographers wearing gloves to be less careful about not handling the tip or shaft of the needle, another source of possible contamination

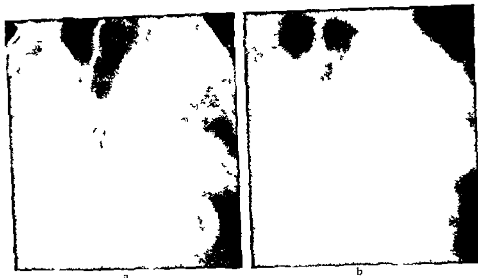
The presence of the few petechial hemorrhages in the five patients in the series who were examined without gloves obviously cannot be explained *on the basis of the powder If the starch derivative powder,* acting as particulate material, can produce this reaction there is no reason why other particulate material cannot do the same SILBERMAN et coll (1960) have reported five cases of foreign body emboli due to cotton fibers being introduced during cerebral angiography CHASON et coll (1963) reported five other cases of cotton fiber embolism, in addition to two cases of cotton fiber implantation into the carotid artery directly during cerebral angiography COGAN et coll *(1961) have reported fat emboli in the retina following* angiography, this was explained on the basis of atheromata being introduced into the blood stream at the site of puncture of the carotid artery Either or both of these explanations may be involved in the five cases of petechial hemorrhages in our series in which gloves were not used

BROMAN & OLSSON (1948 1949) have previously demonstrated the effects of Diodrast on cerebral blood vessels in the rabbit Using various concentrations of Diodrast injected over varying lengths of time, they demonstrated an increase in permeability of the cerebral vessels resulting in edemas, stasis, and punctate hemorrhages

Therefore, it must be assumed that there is more than one mechanism involved in the production of these petechiae, but certainly particulate material must be included as one of these mechanisms

Acknowledgements

I wish to express my appreciation to Dr Nicholas Gonatas and Dr Gabriel Schwarz of the Department of Neurology for their assistance with the microscopic sections and to Dr C Milton Shy and Dr Eli Goldensohn of the Department of Neurology for the use of their animal laboratory



Fg 1 a) Full axial view left subclavian injection no compress on The basilar artery and its branches are seen b) Right common carotid artery compression Forward filling of the right poste or commun cat ng artery and filling of the ght internal carotid artery

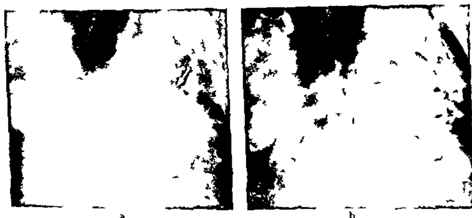


Fig 2 F l a i l ews l ft subcla i n inject on a) Left common c rotid artery compression Forward fill g of l ft nte n l ca otid a tery (arrow) b) B lateral common ca otid artery compres on Fo wa d fil ng f both nternal carot d arteries with filling of all the major arteries forming the c l f W ll s

possible that the right internal carotid tree has filled across the anterior part of the circle of Willis and not through the right posterior communicating artery Previous tests with compression of the right carotid artery only will have shown patency or otherwi e of the right posterior communicating artery

FROM THE RADIODIAGNOSTIC DEPARTMENT, BROOK HOSPITAL, LONDON, ENGLAND

ANGIOGRAPHIC DEMONSTRATION OF THE CIRCLE OF WILLIS

by

LEON MORRIS

At the last Symposium Neuroradiologicum, GRYSPEERDT (1963) described compression tests in vertebral angiography to demonstrate the flow of contrast medium in the posterior part of the circle of Willis Our experience has been largely in agreement with his assessment of these tests

We have, however modified the technique which in the past year we have carried out in the following manner Indirect vertebral angiography is performed by subclavicular catheterisation of the subclavian artery Wherever possible the left side is injected in order to avoid contamination of the intracranial circulation by contrast material injected into the innominate artery and thus into the right common carotid artery

Films are taken with the head in the full axial position Four films are secured 1) without carotid compression (Fig 1 a) 2) with compression of the right common carotid artery (Fig 1 b) 3) with compression of the left common carotid artery (Fig 2 a), and 4) with compression of both common carotid arteries (Fig 2 b)

These multiple compression tests are essential if one is to avoid any error in interpretation which may result from excessive crosss flow in the anterior part of the circle of Willis For example, in the case demonstrated in Fig 2 b, it is

artery Occasionally, only needle puncture of the subclavian artery was possible and in these cases films were exposed in the half axial position

A large enough series of cases of aneurysm treated by carotid occlusion has not been accumulated to assess the significance of our pre operative compression tests but we feel that on the basis of these tests we can give some guidance to the surgeon as to the choice of treatment in each particular case A very large series of cases with pre and post operative studies of the circle of Willis will be necessary before we can draw any valid conclusions concerning the role of the circle of Willis in maintaining blood flow in aneurysm treated by carotid occlusion methods

Acknowledgement

I wish to record my indebtedness to Mr J R Gibbs of the South East Metropolitan Regional Neurosurgical Unit for his assistance and encouragement

SUMMARY

In order to evaluate the circulation in the posterior part of the circle of Willis indirect vertebral angiography is performed and compression tests are carried out with the head in the full axial position The method and results are described

ZUSAMMENFASSUNG

Um die Zirkulation im ruckwartigen Teil des circulus Willisi zu erforschen wurde indirekte *vertebrale* Angiographie durchgefuhrt und Kompressionsteste in axialer Schadellage gemacht Methode und Ergebnisse werden beschrieben

RÉSUMÉ

Pour juger la circulation dans la partie postérieure du cercle de Willis l auteur fait une angiographie *vertébrale indirecte* avec des epreuves de compression la tête étant en hyper extension Il décrit sa méthode et ses résultats

REFERENCE

GRYSPEERDT G L Angiographic studies of the blood flow in the circle of Willis Acta radiol Diagnosis 1 (1963) 298



Fig 3 Half axial view left subclavian injection Bilateral common carotid artery compression All elements of the circle of Willis are seen with some superimposition of the vessels

Certain difficulties have been encountered with this technique

1 Failure to obtain a satisfactory subclavian catheterisation In these cases, and in fact in many cases as a primary procedure, we now use the approach through the axillary artery If necessary, the femoral approach could be used

2 If the right side is injected, one cannot assess accurately spontaneous forward flow in the right posterior communicating artery, because of simultaneous filling of the right common carotid artery

3 Failure to get satisfactory carotid compression

4 Failure to get a good full axial position of the head

If the failure is due to either of these last two factors, one must be satisfied to test the flow in the posterior communicating arteries with the head in the half axial position This allows adequate examination of the flow in the circle of Willis, but excludes the clearer anatomical delineation of the full axial view Fig 3 shows the result achieved with this method

In our small series of cases we have achieved a satisfactory examination in about 60 % In most of the other cases we have obtained much of the information by modifying the procedure as described above In the few cases where we were completely unsuccessful the reason was failure to fill the basilar artery because of a small vertebral artery or an anomalous origin of the vertebral

artery Occasionally, only needle puncture of the subclavian artery was possible and in these cases films were exposed in the half axial position

A large enough series of cases of aneurysm treated by carotid occlusion has not been accumulated to assess the significance of our pre operative compression tests but we feel that on the basis of these tests we can give some guidance to the surgeon as to the choice of treatment in each particular case A very large series of cases with pre and post operative studies of the circle of Willis will be necessary before we can draw any valid conclusions concerning the role of the circle of Willis in maintaining blood flow in aneurysm treated by carotid occlusion methods

Acknowledgement

I wish to record my indebtedness to Mr J R Gibbs of the South East Metropolitan Regional Neurosurgical Unit for his assistance and encouragement

SUMMARY

In order to evaluate the circulation in the posterior part of the circle of Willis indirect vertebral angiography is performed and compression tests are carried out with the head in the full axial position The method and results are described

ZUSAMMENFASSUNG

Um die Zirkulation im ruckwartigen Teil des circulus Willisi zu erforschen wurde indirekte vertebrale Angiographie durchgefuhrt und Kompressionsteste in axialer Schadellage gemacht Methode und Ergebnisse werden beschrieben

RÉSUMÉ

Pour juger la circulation dans la partie postérieure du cercle de Willis l auteur fait une angiographie vertébrale indirecte avec des épreuves de compression la tete etant en hyper extension Il décrit sa méthode et ses résultats

REFERENCE

GRYSPEERDT G L Angiographic studies of the blood flow in the circle of Willis Acta radiol Diagnosis 1 (1963) 298

FROM THE DEPARTMENT OF RADIOLOGY AND THE DIVISION OF NEUROLOGICAL SURGERY, DEPARTMENT OF SURGERY, UNIVERSITY OF CALIFORNIA SCHOOL OF MEDICINE, SAN FRANCISCO, CALIFORNIA, U S A

VERTEBRAL ARTERIOVENOUS FISTULA COMPLICATING VERTEBRAL ANGIOGRAPHY

by

THOMAS H NEWTON and JOHN DARROCH

The need for detailed vertebral angiography has increased with advances in neurosurgical techniques and many approaches have been described Direct percutaneous puncture of the vertebral artery in the neck (LINDGREN 1950, MONES 1961, SUGAR, HOLDEN & POWELL 1949 and SUTTON 1962) is the most common method for vertebral angiography The techniques as recommended by various authors have differed primarily in the level of arterial puncture and the type of needle used

The most commonly reported complication of vertebral angiography is transient occipital lobe dysfunction with visual field defects (SILVERMAN, BERGMAN & BENDER 1961) Failures in technique have resulted in extravasation of contrast medium, hematomas, occlusion of the vertebral artery, and brachial plexus injury Arteriovenous fistula of the vertebral artery as a complication of direct vertebral arteriography has been reported previously in only four patients (OLSON, HILLIER & SVIEN 1963, PHILIPSSON & KARNELL 1956, and SUTTON 1962)

The present report concerns five patients in whom vertebral arteriovenous fistula was the result of percutaneous puncture of the vertebral artery



Fig 1 Cas 1 a) Right vertebral ang ogr phy Perfe t place ner t of the needle with nc ev dence of e tr vas tion b) and c) Retrograde right brachial ang ography Enlarged proximal right verte bral artery early fill ng of vertebral v nous plexus (arrows)

Case reports

Ca e I A 33 year-old Negro woman vas first seen at the hospital in 1952 Hypertension had been discovered after a transient left sided hemiparesis when she was 26 years old In 1960 she complained of sudden frontal headache and somnolence Minimal residual signs of left sided weakness v ere present on neurological examination The cerebrospinal fluid was grossly bloody

Bilateral carotid angi raphies in July 1960 showed no definite abnormality Attempts at percutaneous puncture of both vertebral arteries were unsuccessful Percutaneous right ertebral angiography repeated in August 1960 showed no abnormality (Fig 1 a) Shortly afterwards the patient noted pain along the distribution of the median nerve in both arms associated with slight hypesthesia These symptoms gradually subsided

In December 1960 continuous to-and fro murmurs were heard over both sides of the neck She was r admitted in September 1961 for investigation of a bruit and a machinery like murmur l muted to the right side of the neck A right common carotid angiography was normal On Sept 19 1961 retrograde right brachial angiography showed enlargement of the proximal portion of the right vertebral artery and early filling of the vertebral venous plexus (Fig 1 b and The distal right vertebral and basilar arteries filled well The left vertebral artery





Fig. 2. Case 1. *Left.* Transaxillary left vertebral angiography. Enlarged proximal left vertebral artery. No contrast medium in the distal left vertebral artery. Immediate filling of the paravertebral venous plexus. *Right.* Later phase. Dilated vertebral vein draining the paravertebral venous plexus.

Fig. 3. Case 2. Inadvertent injection into the left vertebral artery. Partial extravasation into the venous plexus.

was not examined at this time. The right vertebral arteriovenous fistula appeared to be at the level of C 5. It was considered asymptomatic and surgical repair was deemed inadvisable.

The patient returned in September 1963 because of sudden onset of slurred speech and right hemiparesis, both of which cleared slowly. She had also noted dizzy spells and episodes of generalized weakness. On physical examination, a thrill in the left side of the neck below the level of the carotid bifurcation could be felt. A machinery-like murmur was noted in the region of both supraclavicular fossae but was more evident on the left side. Transaxillary left vertebral angiography showed a large proximal left vertebral artery patent to the level of C 5 (Fig. 2, left view). No contrast material was seen in the distal left vertebral artery. The contrast medium rapidly filled a large paravertebral venous plexus which drained into a dilated vertebral vein (Fig. 2, right). Transaxillary right subclavian angiography showed that the right vertebral artery was normal and that the previously noted fistula on the right side had closed spontaneously. No significant relationship appeared to exist between the patient's symptoms and the arteriovenous fistula of the left vertebral artery; surgical intervention was therefore not advised.

Comment. Bilateral vertebral arteriovenous fistulas were the result of attempted puncture of the vertebral arteries. Of interest in this patient is the documented spontaneous closure of the fistula on the right side.



Fig 4 Case 2 a) Left vertebral angiography Dilated proximal left vertebral artery with immediate filling of the paravertebral venous plexus b) *Later phase* Communication with a dilated paravertebral venous plexus right

Case 2 A 38 year-old white woman was first admitted in 1956 for treatment of a long standing convulsive disorder Injury to her head at the age of 12 years had been followed by persistent intermittent suboccipital and bitemporal headaches occasionally associated with transitory vertigo At the age of 24 she had undergone a right parieto-occipital craniotomy with removal of a chronic subdural hematoma After the surgical procedure a left hemiparesis had developed and gradually cleared A year after the operation the first convulsion had occurred A left craniotomy had been done in 1954 to divide the tentorium

On physical examination at admission in 1956 a dense symmetrical congruous homonymous quadrantanopsis was noted Bilateral common carotid angiographies showed no abnormalities During the initial injection on the left however partial filling of the vertebral artery and adjacent venous plexus was observed (Fig 3)

The patient was readmitted in 1962 complaining of occasional loss of equilibrium and sudden falls without loss of consciousness On physical examination at that time a loud systolic murmur and a bruit which did not disappear on carotid compression were heard in the left side of the neck A left vertebral angiography using the femoral artery approach showed that the proximal left vertebral artery was large although its distal caliber appeared normal Fig 4a The contrast medium entered the vertebral venous plexus at the level of C 5 On later roentgenograms the contrast medium was seen to cross the midline to fill the vein





Fig 2 Case 1 *Left* Transaxillary left vertebral angiography Enlarged proximal left vertebral artery No contrast medium in the distal left vertebral artery Immediate filling of the paravertebral venous plexus *Right* Later phase Dilated vertebral vein draining the paravertebral venous plexus



Fig 3 Case 2 Inadvertent injection into the left vertebral artery Partial extravasation into the venous plexus

was not examined at this time The right vertebral arteriovenous fistula appeared to be at the level of C 5 It was considered asymptomatic and surgical repair was deemed inadvisable

The patient returned in September 1963 because of sudden onset of slurred speech and right hemiparesis both of which cleared slowly She had also noted dizzy spells and episodes of generalized weakness On physical examination a thrill in the left side of the neck below the level of the carotid bifurcation could be felt A machinery like murmur was noted in the region of both supraclavicular fossae but was more evident on the left side Transaxillary left vertebral angiography showed a large proximal left vertebral artery patent to the level of C 5 (Fig 2 left view) No contrast material was seen in the distal left vertebral artery The contrast medium rapidly filled a large paravertebral venous plexus which drained into a dilated vertebral vein (Fig 2 right) Transaxillary right subclavian angiography showed that the right vertebral artery was normal and that the previously noted fistula on the right side had closed spontaneously No significant relationship appeared to exist between the patient s symptoms and the arteriovenous fistula of the left vertebral artery surgical intervention was therefore not advised

Comment Bilateral vertebral arteriovenous fistulas were the result of attempted puncture of the vertebral arteries Of interest in this patient is the documented spontaneous closure of the fistula on the right side

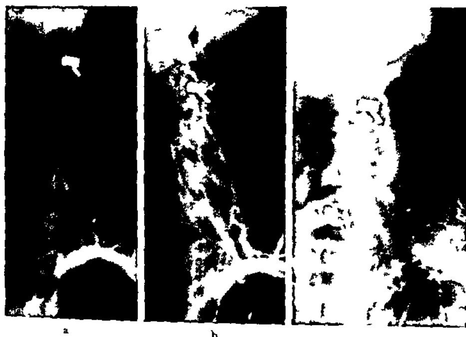


Fig 6 Case 3 a) Left subclavian angiography Occlusion of proximal left vertebral artery b) and c) Later phases Contrast filling of the distal left vertebral artery by collateral channels Early filling of the vertebral venous plexus and of a dilated vertebral vein (two arrows)

ear synchronous with the heart beat A loud bruit heard over the entire left neck was not obliterated by compression of the carotid artery A retrograde aortography suggested the presence of an arteriovenous fistula of the vertebral artery The bruit heard at the level of C 5 –6 disappeared after surgical ligation of the proximal left vertebral artery

Readmitted in October 196 On physical examination a loud systolic bruit on the left side of the neck was again heard A left subclavian angiography in January 1963 showed that the proximal portion of the left vertebral artery was occluded (Fig 6 a) The ascending cervical artery as well as the branches of the thyrocervical and costocervical trunks communicated with the vertebral venous plexus The distal left vertebral artery was small and was filled by collateral channels (Fig 6 b) Early filling of a prominent vertebral vein was seen (Fig 6 c) A right subclavian angiography showed that the fistula was also fed by reversal of flow down the left vertebral artery Small branches of the right thyrocervical trunk contributed further to flow through the fistula (Fig 7 a and b)

Comment The vertebral arteriovenous fistula resulting from needle trauma was not cured by surgical occlusion of the proximal left vertebral artery One year after operation the left sided fistula was fed by branches of the left costocervical and thyrocervical trunk Collateral branches of the right thyrocervical trunk and reversal of flow down the distal left vertebral artery also contributed to the fistula



Fig. 5. Case 3. Left vertebral angiography. Faulty placement of the needle with immediate filling of vertebral venous plexus with contrast medium.

on the right as well as on the left side (Fig. 4 b). (The puncture of the vertebral artery in 1956 6 years previously had been at the same level as the present arteriovenous fistula.) A right vertebral angiography appeared to be normal with no evidence of reflux into the left vertebral artery. On surgical exploration of the vertebral arteriovenous fistula arterial blood was seen to be coursing through the vertebral venous plexus adjacent to the vertebral artery. A 5 mm segment of the vertebral artery was resected at the level of the fistula and the thrill and bruit disappeared.

The patient was last seen 1 1/2 years after the operation. At that time the convulsions were controlled medically and no bruits or murmurs were heard in the neck.

Comment. Trauma of the vertebral artery at the time of carotid angiography resulted in vertebral arteriovenous fistula. The fistula was completely obliterated by resection of the vertebral artery at the site of the fistula.

Case 3. When first seen in 1951 a 16 year old white girl had a tremor of the right arm and hand of 2 months duration. On physical examination a rhythmic tremor without increase in tone was present in the right upper extremity. The tremor tended to disappear or decrease with sleep. Bilateral carotid angiographies were normal.

The patient was readmitted in July 1961 complaining of a strange feeling in the right arm as well as headaches of 5 months duration. The tremor in the right arm had continued and the right side was slightly weak. An encephalography as well as left vertebral and left carotid angiographies were normal at that time. The placement of the needle for the vertebral angiography however was faulty and some filling of the vertebral veins was noted (Fig. 5).

On readmission in December 1961 the patient complained of a blowing noise in the left

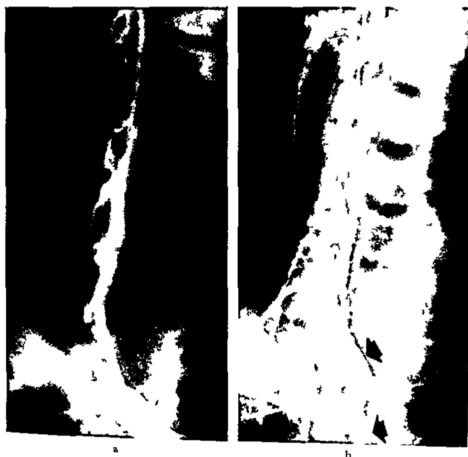


Fig 8 Case 4 a) Transaxillary right vertebral angiography Immediate filling of vertebral venous plexus Distal vertebral artery is smaller than the proximal vertebral artery b) Late arterial phase Early filling of dilated vertebral vein

the vertebral artery (Fig 8 b) After exploration of the vertebral arteriovenous fistula and ligation of numerous veins in the area the bruit disappeared

Comment A direct vertebral artery puncture resulted in a vertebral arteriovenous fistula

Case 5 A history of two transient episodes of hemiparesis each affecting a different side of the body was obtained from this 36-year-old white man In July 1960 bilateral carotid angiographies were normal A right subclavian angiography had failed to demonstrate the vertebral artery A satisfactory left vertebral angiography had been obtained by direct percutaneous puncture at the level of C 5—6 Cerebral vascular occlusive disease had been diagnosed and the hemiparesis had been attributed to transient ischemic attacks

The patient was first seen at the University of Minnesota Hospital in January 1961 com



Fig. 7. Case 3. a) Branches of the right thyrocervical trunk contribute to left vertebral arteriovenous fistula. b) Late arterial phase. Reversal of flow down the left vertebral artery represents further contribution to the left vertebral arteriovenous fistula.

Case 4. A 39 year old white man had a sudden episode of severe occipital headache in January 1963. Deep tendon reflexes were slightly hyperactive and slight nuchal rigidity was present. A lumbar puncture revealed blood in the spinal fluid. Bilateral carotid angiographies showed no abnormality. Attempted left vertebral angiography was unsuccessful. The patient was readmitted two months later complaining of occasional occipital headaches. On physical examination no abnormalities were noted. Bilateral carotid angiographies were again normal. A direct right percutaneous vertebral angiography resulted in a partial subintimal and extraluminal injection. At the level of C 2 the vertebral artery was narrow with contrast material extending only to the level of C 1.

The patient was readmitted one year later because of a pulsatile noise in his head. On physical examination, a murmur was heard in the right side of the neck. Carotid or jugular compression did not decrease the bruit, but rotation of the head to either direction markedly diminished it. At a right vertebral angiography, using the transaxillary catheter technique, the distal right vertebral artery was relatively small. A fistulous communication between the vertebral artery and venous plexus was observed at the level of C 5 (Fig. 8 a). Later roentgenograms of the same series showed a large single vertebral vein adjacent to the first portion of

Discussion

Previous reports of vertebral arteriovenous fistulas have stressed their rarity The vertebral artery is well protected within the transverse cervical canal and is therefore not susceptible to injury Most of the fistulas that have been reported were the result of penetrating injuries to the vertebral artery from either gunshot or stab wounds (CHOU & FRENCH 1965 ELKIN & HARRIS 1946 HEIFETZ 1945 JEFFERSON BAILEY & KERR 1956 KUTTNER 1917 SHUMACKER 1946) Three patients with vertebral arteriovenous fistulas resulting from blunt trauma to the head or neck (ARONSON 1961 ELKIN and HARRIS 1946 FAETH & DUEKER 1961) and one patient with a spontaneous fistula have been described (GOODDY & SCHECHTER 1960) SUGAR, HOLDEN & POWELL (1949) first suggested the possibility of producing a vertebral arteriovenous fistula by damaging the vertebral artery and vein during vertebral angiography or by inadvertently puncturing the vertebral artery at the time of attempted carotid angiography, but only four fistulas have been reported

Anatomic considerations This paucity of reports of fistulas following puncture of the vertebral artery is surprising considering the anatomic relationship of the vertebral artery to the adjacent venous plexus This relationship which has been described previously (GREITZ LILLIEQUIST & MULLER 1962 PERRIG 1931) was confirmed by us by anatomic dissection of these vessels By injecting colored latex into one of the cervical vertebral bodies the vertebral venous plexus could easily be filled and the dissection simplified Anatomic roentgenologic studies with injection of contrast medium into a cervical vertebral body also demonstrated the vertebral venous plexus

The extracranial vertebral artery may be divided into 3 parts From its origin at the subclavian artery, the first portion extends to its entrance into the transverse foramen usually at the level of the sixth cervical vertebra The second portion of the artery lies within the canal transversarium and ends at its exit from the atlas The third portion suboccipital in location extends from its exit from the atlas to its entrance into the skull

In its second portion within the bony canal a venous plexus completely surrounds the vertebral artery The veins communicate freely with the epidural longitudinal vertebral sinuses the basivertebral vein and the prevertebral veins (GREITZ LILLIEQUIST & MULLER 1962) The vertebral venous plexus drains into a single vertebral vein that lies somewhat lateral and anterior to the first portion of the vertebral artery This vertebral vein enters the internal jugular vein near its junction with the subclavian vein

Clinical features The diagnosis of a vertebral arteriovenous fistula may be

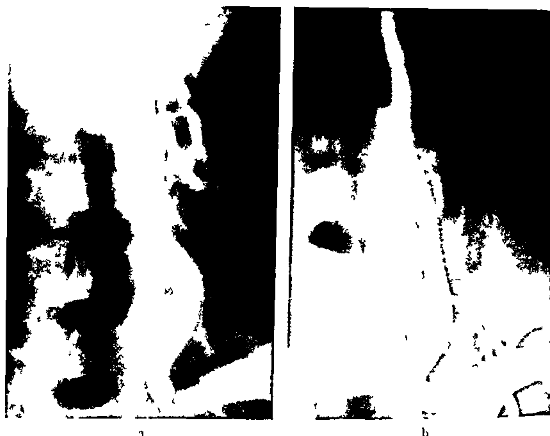


Fig 9 Case 5 a) Left vertebral angiography Immediate filling of dilated venous plexus b) Postoperative angiography Vertebral artery is normal with no evidence of fistula (From Chou S N & French L A Reprinted with permission)

plaining of a rhythmic pulsatile noise in the neck present since the previous angiography On physical examination a loud bruit with systolic and diastolic components was noted in the neck The bruit was obliterated by head turning to the right hyperextension or compression of the carotid artery Bilateral carotid angiographies showed no abnormality A right subclavian angiography showed partial arteriosclerotic narrowing at the origin of the right vertebral artery An arteriovenous fistula of the vertebral artery at the level of C5—6 (Fig 9 a) was revealed on left subclavian angiography In March 1961 the fistula was explored Numerous venous channels were noted anterior medial and lateral to the vertebral artery These were dissected free of the artery and coagulated The fistula itself was not identified but the bruit disappeared A left vertebral angiography in January 1963 showed this vessel to be normal with no evidence of residual fistula (Fig 9 b)

Comment In this case the fistula apparently followed a direct percutaneous vertebral angiography that was technically uncomplicated Unlike those in the other cases this bruit was obliterated by carotid compression (The data in this case have been reported by Chou & French and have been reprinted with the permission of the authors and of J Neurosurg)

Discussion

Previous reports of vertebral arteriovenous fistulas have stressed their rarity The vertebral artery is well protected within the transverse cervical canal and is therefore not susceptible to injury Most of the fistulas that have been reported were the result of penetrating injuries to the vertebral artery from either gunshot or stab wounds (CHOU & FRENCH 1965 ELKIN & HARRIS 1946 HEIFETZ 1945 JEFFERSON, BAILEY & KERR 1956 KUTTNER 1917 SHUMACKER 1946) Three patients with vertebral arteriovenous fistulas resulting from blunt trauma to the head or neck (ARONSON 1961, ELKIN and HARRIS 1946 FAETH & DUEKER 1961) and one patient with a spontaneous fistula have been described (GOODDY & SCHECHTER 1960) SUGAR HOLDEN & POWELL (1949) first suggested the possibility of producing a vertebral arteriovenous fistula by damaging the vertebral artery and vein during vertebral angiography or by inadvertently puncturing the vertebral artery at the time of attempted carotid angiography but only four fistulas have been reported

Anatomic considerations This paucity of reports of fistulas following puncture of the vertebral artery is surprising considering the anatomic relationship of the vertebral artery to the adjacent venous plexus This relationship which has been described previously (GREITZ, LILIEQUIST & MULLER 1962 PERRIG 1931) was confirmed by us by anatomic dissection of these vessels By injecting colored latex into one of the cervical vertebral bodies the vertebral venous plexus could easily be filled and the dissection simplified Anatomic roentgenologic studies with injection of contrast medium into a cervical vertebral body also demonstrated the vertebral venous plexus

The extracranial vertebral artery may be divided into 3 parts From its origin at the subclavian artery the first portion extends to its entrance into the transverse foramen usually at the level of the sixth cervical vertebra The second portion of the artery lies within the canal transversarium and ends at its exit from the atlas The third portion suboccipital in location extends from its exit from the atlas to its entrance into the skull

In its second portion within the bony canal a venous plexus completely surrounds the vertebral artery The veins communicate freely with the epidural longitudinal vertebral sinuses the basivertebral vein and the prevertebral veins (GREITZ LILIEQUIST & MULLER 1962) The vertebral venous plexus drains into a single vertebral vein that lies somewhat lateral and anterior to the first portion of the vertebral artery This vertebral vein enters the internal jugular vein near its junction with the subclavian vein

Clinical features The diagnosis of a vertebral arteriovenous fistula may be

suspected by the presence of a pulsatile bruit in the neck, which is often audible to the patient In most cases, the murmur is not affected by carotid compression This clinical test however is not reliable since compression of the carotid artery usually results in simultaneous compression of the jugular vein The elevation of venous pressure on compression of the jugular vein may decrease the flow through the vertebral arteriovenous fistula and thus stop the bruit

Accurate angiography, then, is essential to establish the correct diagnosis as well as to determine the level of the fistula Moreover, demonstration of any collateral arterial supply to the fistula is important in the surgical management of these patients Branches of the thyrocervical or costocervical trunk may contribute to the fistula, or the flow in the distal vertebral artery may be reversed towards the fistula Such alternate collateral branches are probably more common in the chronically established fistula, especially one treated by simple ligation of the proximal vertebral artery

Treatment of vertebral arteriovenous fistulas has been described previously (Chou & French 1965, Kuttner 1917, Perric 1931) and is outside the scope of this report Important to emphasize however is the usual inadequacy of simple ligation of the proximal vertebral artery and the necessity of obliterating the fistula itself

Radiologic considerations Percutaneous puncture of the vertebral artery probably always results in minor damage to the surrounding venous plexus Moreover, with imperfect puncture and needle placement, contrast material may occasionally be injected partly into the artery and partly into the venous plexus In some instances such trauma probably results in temporary arteriovenous communications that close spontaneously

Arteriovenous fistula of the vertebral artery is easily diagnosed after the injection of contrast medium into the proximal vertebral artery The exact site of the fistula may be difficult to ascertain however because of overlying contrast filled veins As with fistulas in other locations, the proximal artery and draining veins were enlarged in most of our patients

Six other patients, in whom partial venous filling had been noted at vertebral angiography were re-examined clinically following the angiography None of these patients had noted any pulsatile noises nor were bruits heard in the neck Repeated vertebral angiography in 2 of these patients showed the vertebral artery to be intact

In order to prevent the formation of an arteriovenous fistula following vertebral angiography, direct puncture of the vertebral artery must be avoided All methods of angiography have certain risks and each investigator must choose an approach which in his hands has the least complications Since

1963 catheter techniques have been used in vertebral angiography at the University of California Hospital in San Francisco in most instances In children and young adults the transfemoral route is chosen and a polyethylene catheter is advanced into the left vertebral artery In older patients the trans axillary approach is used and the catheter is placed into the proximal right vertebral artery Usually catheterization of the right vertebral artery presents no difficulty but occasionally the catheter cannot be maneuvered easily into this artery In these instances an injection with the catheter tip in the subclavian artery usually results in adequate contrast filling of the vertebrobasilar vessels Catheter techniques have advantages other than the prevention of arteriovenous fistula only local anesthesia with minimal premedication is necessary a careful unhurried examination in any desired position is also possible something that is often difficult with direct puncture of the vertebral artery

SUMMARY

Five patients with angiographically demonstrated vertebral arteriovenous fistulas resulting from percutaneous puncture of the vertebral artery are reported The intimate relationship of the vertebral artery and its surrounding venous plexus is stressed The use of catheter techniques is recommended to avoid this complication

ZUSAMMENFASSUNG

Es wird uber 5 Patienten mit angiographisch darstellbaren vertebralen arteriovenosen Fisteln nach perkutaner Punktion der Aorta vertebralis berichtet Die intime Beziehung der Vertebralarterie mit dem sie umgebenden Venenplexus wird hervorgehoben Um diese Komplikation zu verhindern wird die Anwendung der Kathetertechnik empfohlen

RÉSUMÉ

Présentation de cinq malades atteints de fistule artérioveineuse vertébrale prouvée par angiographie et résultant de ponction percutanee de l artère vertébrale Les auteurs soulignent les rapports étroits de l artère vertébrale avec les plexus veineux qui l entourent Ils recommandent le cathéterisme pour éviter cette complication

REFERENCES

ARONSON N I Traumatic arteriovenous fistula of the vertebral vessels angiographic demonstration and a rationale for treatment Neurology 11 (1961) 817
CHOU S N and FRENCH L A Arteriovenous fistula of vertebral vessels in the neck J Neurosurg 24 (1965) 77
ELKIN D C and HARRIS M H Arteriovenous aneurysm of vertebral vessels report of 10 cases Ann Surg 124 (1946) 934

FAETH W H and DUEKER H W Arteriovenous vascular malformation of the cervical portion of the vertebral artery a case report Neurology 11 (1961) 492

GOODDY W and SCHECHTER M M Spontaneous arterio venous fistula of the vertebral artery case report Brit J Radiol 33 (1960) 709

GREITZ T LILIEQUIST B and MÜLLER R Cervical vertebral phlebography Acta radiol 57 (1962) 353

HEIFETZ C J Traumatic aneurysm of first portion of left vertebral artery case report Ann Surg 122 (1945) 102

JEFFERSON C BAILEY R A and KERR A S Suboccipital arteriovenous aneurysms of vertebral artery J Bone Jt Surg 38B (1956) 114

KUTTNER H Die Verletzungen und traumatischen Aneurysmen der Vertebralgefässe am Halse und ihre operative Behandlung Beitr z klin Chir 108 (1917) 1

LINDGREN E Percutaneous angiography of vertebral artery Acta radiol 33 (1950) 389

MONES R Vertebral angiography, an analysis of 106 cases Radiology 76 (1961) 230

OLSON R W HILLIER L B JR and SWEN H J Arteriovenous fistula a complication of vertebral angiography, report of a case J Neurosurg 20 (1963) 73

PERRIG H Zur Anatomie Klinik und Therapie der Verletzungen und Aneurysmen der Arteria vertebralis Beitr z klin Chir 154 (1931) 272

PHILIPSSON J and KARNELI J Arteriovenös fistel efter punktion av a vertebralis för cerebral angiografi Opusc med (Stockh) 1 (1956) 49

SHUMACKER H B JR Arteriovenous fistulas of cervical portion of vertebral vessels Surg Gynec Obstet 83 (1946) 625

SILVERMAN S M BERGMAN P S and BENDER M B The dynamics of transient cerebral blindness report of nine episodes following vertebral angiography Arch Neurol 4 (1961) 333

SUGAR O HOLDEN L B and POWELL C B Vertebral angiography Amer J Roentgenol 61 (1949) 166

SUTTON D Arteriography E & S Livingstone Ltd Edinburgh 1962

CLINIQUE OPHTALMOLOGIQUE (PROF G OFFRET) HOTEL DIEU ET SERVICE NEURORADIOLOGIQUE (PROF H FISCHGOLD) HOPITAL DE LA PITIE PARIS, FRANCE

LE PHLEBOGRAMME ORBITAIRE

par

G OFFRET D ARON ROSA J METZGER et D DOYON

L exploration du systeme veineux de l orbite a deja fait l objet de plusieurs travaux en France notamment ceux de BOUDET (1953—1954)

Si l on connait bien grace a l anatomie classique aux ouvrages specialisés (WOLFF s 1961 HENRY 1959) l aspect anatomique du reseau veineux orbitaire on ne peut en dire autant de son aspect radiologique

Avec le concours de Professeur Fischgold nous avons essaye de codifier l interprétation de la phlebographie orbitaire

Technique Apres denudation de la veine angulaire sous anesthesie locale nous *cathétérisons* la veine directement avec une aiguille a injection intra veineuse de calibre moyen reliee a une seringue contenant du serum physiologique par *un tube* de 10 cm de long en plastique (polyethylene) Une fois l aiguille bien en place le sang refluant a l aspiration et la seringue se vidant sous faible pression du piston on installe le malade pour l incidence de profil, ensuite de face faisant couler du *sérum* constamment entre chaque injection de produit opaque pour eviter la coagulation dans l aiguille 7 ml de Vasurix 25 ou de Radioselectan a 60 % *sont injectés* à la seringue automatique sous 3 kg de pression ou à defaut à la main en 2 ou 3 secondes

Nous utilisons un seriographe rapide automatique cadence de prise de

LAETH W H and DUKER H W Arteriovenous vascular malformation of the cervical portion of the vertebral artery a case report Neurology 11 (1961) 492

GOODDY W and SCHECHTER M M Spontaneous arterio venous fistula of the vertebral artery case report Brit J Radiol 33 (1960) 709

GREITZ T LINDQUIST B and MÜLLER R Cervical vertebral phlebography Acta radiol 57 (1962) 353

HEIFETZ C J Traumatic aneurysm of first portion of left vertebral artery case report Ann Surg 122 (1945) 102

JEFFERSON G BAILEY R A and KERR A S Suboccipital arteriovenous aneurysms of vertebral artery J Bone Jt Surg 38B (1956) 114

KUTTNER H Die Verletzungen und traumatischen Aneurysmen der Vertebralgefässe am Halse und ihre operative Behandlung Beitr z klin Chir 108 (1917), 1

LINDGREN E Percutaneous angiography of vertebral artery Acta radiol 33 (1950) 389

MONES R Vertebral angiography an analysis of 106 cases Radiology 76 (1961) 230

OLSON R W HILLIER L B JR and SMITH H J Arteriovenous fistula a complication of vertebral angiography report of a case J Neurosurg 20 (1963) 73

PERRIG H Zur Anatomie Klinik und Therapie der Verletzungen und Aneurysmen der Arteria vertebralis Beitr z klin Chir 154 (1931) 272

PHILIPSSON J and KARNELL J Arteriovenös fistel efter punktion av a vertebralis för cerebral angiografi Opusc med (Stockh) 1 (1956) 49

SHUMACKER H B JR Arteriovenous fistulas of cervical portion of vertebral vessels Surg Gynec Obstet 83 (1946) 625

SILVERMAN S M BERGMAN P S and BENDER M B The dynamics of transient cerebral blindness report of nine episodes following vertebral angiography Arch Neurol 4 (1961) 333

SUGAR O HOLDEN L B and POWELL C B Vertebral angiography Amer J Roentgenol 61 (1949) 166

SUTTON D Arteriography E & S Livingstone Ltd Edinburgh 1962

CLINIQUE OPHTALMOLOGIQUE (PROF G OFFRET) HOTEL DIEU ET SERVICE NEURORADIOLOGIQUE (PROF H FISCHGOLD), HOPITAL DE LA PITIE PARIS, FRANCE

LE PHLEBOGRAMME ORBITAIRE

par

G Offret, D Aron Rosa J Metzger et D Doyon

L exploration du systeme veineux de l orbite a deja fait l objet de plusieurs *travaux* en France notamment ceux de Boudet (1953—1954)

Si l on connait bien grace a l anatomie classique aux ouvrages specialises (Wolff s 1961 Henry 1959) l aspect anatomique du reseau veineux orbitaire on ne peut en dire autant de son aspect radiologique

Avec le concours de Professeur Fischgold nous avons essaye de codifier l *interprétation* de la phlebographie orbitaire

Technique Apres denudation de la veine angulaire sous anesthésie locale nous cathéterisons la veine *directement* avec une aiguille a injection intra veineuse de calibre moyen *reliée* a une seringue contenant du serum physiologique par un tube de 10 *cm de long* en plastique (polyethylene) Une fois l aiguille bien en place le sang refluant à l aspiration et la seringue se vidant sous faible pression du piston *on* installe le malade pour l incidence de profil ensuite de face laisant couler du serum constamment entre chaque injection de produit opaque pour éviter la coagulation dans l aiguille, 7 ml de Vasurix 25 ou de Radioselectan à 60 % sont injectés a la seringue automatique sous 3 kg de pression ou à défaut a la *main en* 2 ou 3 secondes

Nous utilisons un seriographe *rapide* automatique cadence de prise de



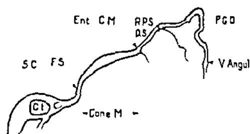


Fig. 1. Phlébogramme orbitaire normal de profil. P.G.O. indique poulie du grand oblique. R.P.S. releveur de la paupière supérieure. D.S. droit supérieur. Ent. C.M. entrée dans le cône musculaire. F.S. passage dans la fente sphénoïdale. S.C. sinus caverneux. C.I. carotide interne. V. Angul. veine angulaire.

films de 1 par seconde, un premier film est pris au temps 0 juste avant l'injection pour servir à la soustraction, le dernier film est tiré à la 15ème seconde. On se contente d'un cliché toutes les deux ou trois secondes à partir de la 3ème seconde, nous utilisons généralement 7 films pour chaque incidence.

Le générateur et le tube de rayons roentgen doivent pouvoir donner des temps de pose courts, de l'ordre de 1/10 de seconde.

Tous les clichés sont soustraits pour obtenir un meilleur contraste de l'image par effacement des ombres osseuses nombreuses au niveau de l'orbite.

Les incidences.

1. De profil, cliché centré sur l'orbite, en diaphragmant au maximum pour améliorer les contrastes, avec des constantes légèrement inférieures à celles d'un profil standard du crâne,

2. De face occiput plaque, rayon passant par le milieu de l'orbite incliné d'environ 10° sur le plan de Virchow dans le sens caudo cranial, pour que les rochers se projettent au dessous de la clarté orbitaire, en diaphragmant, mais en radiographiant simultanément les deux orbites.

3. Incidence axiale. Nous n'avons fait que quelques essais de cette incidence difficile à réaliser, l'aiguille quittant la veine lors de la mobilisation de la tête; cette incidence s'annonce pourtant intéressante.

Plus récemment nous avons commencé à mesurer systématiquement les pressions veineuses (par un manomètre de Claude gradué en centimètres d'eau) au repos, après manœuvre de compression des jugulaires et après arrêt de cette compression.

Tolérance de l'examen. L'injection du produit opaque est indolore.

La cicatrice secondaire à la dénudation est minime passant aussi inaperçue que celle d'une incision pour intervention sur le sac lacrymal.



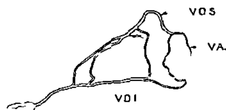


Fig 2 Phlebogramme orbitaire normal de profil autre variété opacification de la veine ophtalmique inferieure V A indique veine angulaire V O S veine orbitaire supérieure V O I veine orbitaire inferieure

Nous n avons eu aucun accident et seulement trois incidents sur une trentaine d examens une injection sous cutanee qui s est resorbée sans douleur en quelques minutes et deux veines angulaires non catheterisables dans un de ces cas une veine frontale a ete injectee par erreur la veine angulaire n'ayant pu etre repérée dans l autre cas il s agissait d une malade operee a qui l on avait lié la veine ophtalmique superieure

Enfin il faut signaler que pour l ophtalmologue et le radiologue, il n y a pas de risque d irradiation avec le sériographe et la seringue automatique, la prise des cliches et la seringue etant declenches d une cabine de commande protégee

Resultats

Phlebographie normale

Les images des courants veineux de l orbite et de la veine ophtalmique superieure en particulier sont suffisamment constantes pour qu on puisse en faire un schema morphologique topographique et chronologique (hemodynamique) auquel pourront etre comparees les diverses images pathologiques rencontrées

Divers points devront etre etudiés la morphologie des images veineuses et leur place dans l orbite sur les cliches de profil et de face le remplissage éventuel du systeme anastomotique et du systeme veineux orbitaire controlateral l opacification du sinus caverneux et ses differents types enfin nous décrirons les premiers resultats de l etude des pressions dans la veine angulaire et de la mesure des temps de circulation veineuse du systeme orbito caverneux

Phlebogramme orbitaire en incidence de profil La veine ophtalmique superieure ou principale (Fig 1) sinueuse fait suite à l angulaire et penetre dans l orbite



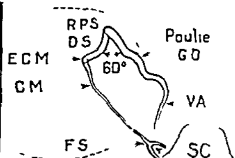


Fig. 3. Phlebogramme orbitaire normal de face. Angle superieur de 60° à l'entree de la veine dans la gaine du droit superieur (D.S.) et du releveur de la paupiere superieure (R.P.S.). E.C.M. indique le point d'entree dans le cone musculaire. Remarquer la longueur du trajet libre dans le cone musculaire (C.M.). V.A. indique veine angulaire. F.S. fente sphenoidale. S.C. sinus caverneux.

bridee par la poulie du grand oblique, qui lui fait decrire une anse concave en bas, c'est le premier point fixe au dela duquel elle reçoit souvent une racine accessoire, elle parcourt ainsi le 1/3 superieur de l'orbite.

La veine chemine, plaquee contre le toit de l'orbite au dessus du cone musculaire, *au dessus donc des releveurs et droit superieur.*

A l'union du 1/3 anterieur et du 1/3 moyen de l'orbite, la veine ophtalmique superieure s'incline par un mouvement oblique en bas et en arriere et sur un court trajet contourne le bord lateral des releveurs et du droit superieur, plaquée contre leur gaine, penetrant ensuite dans le cone musculaire : *c'est le 2eme point fixe.*

A l'intérieur du cone la veine se dirige en arriere et en bas, croise dans l'espace le nerf optique et sort par la fente sphénoidale pour aboutir au pole anterieur du sinus caverneux.

Dans son trajet elle reçoit (Fig. 2) des veines musculaires et deux veines vortiqueuses ainsi que les collatérales, rarement et *incompletement* visibles.

Quelquefois on trouve individualisee une grele veine inferieure, reunies à la veine ophtalmique superieure par une ou plusieurs anastomoses verticales, c'est la veine ophtalmique inferieure, simple veine musculaire qui suit le plancher de l'orbite et se jette, soit dans la partie terminale de la veine ophtalmique superieure, soit directement dans le sinus caverneux.

Quant à la veine ophtalmique moyenne, située entre ces deux veines et encore plus grele, nous ne l'avons jamais individualisee.

Le calibre de ces veines est assez variable radiologiquement, la limite maximum normale de la veine ophtalmique supérieure est de 1,5 à 2 mm, celle de la veine ophtalmique inferieure de 1 à 1,5 mm.

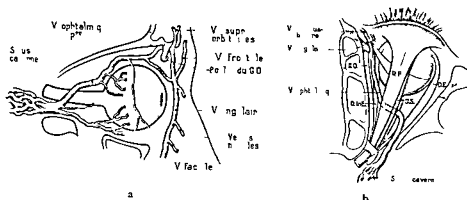


Fig 4 Schemas anatom ques des veines de l orbite a) Vue externe b) Vue superieu e G O nd que grand obl que R P rele eur de la paupiere D S droit superieur D E droit externe D int d oit nterne

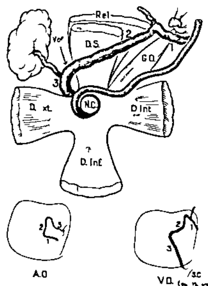


Fig 5 Schéma anatom que et projection radiologique des eine et artere ophtalmique Vue de face On peut decrire t ois segments 1 — de la poul e du grand oblique (G O) à la gaine des muscles dro t superieur (D S) et releveur (Rel) 2 — segment dans la gaine des muscles droit superieur et releveur 3 — segment intra-conique N O nd que nerf opt que D ext droit externe D nt dro t interne D inf droit inferieur

L opacification bilatérale des systemes veineux orbitaires rend la lecture des images difficile sur le profil

En conclusion de profil existent d importants reperes fixes dans ce phlébogramme poulis du grand oblique plafond de l orbite pénetration dans le cone musculaire arrivée au sinus caverneux ce sont les segments contenus entre les points fixes qui modifient leur aspect sous l influence des deplacements tumoraux



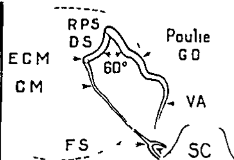


Fig. 3. Phlébogramme orbitaire normal de face. Angle supérieur de 60° à l'entrée de la veine dans la gaine du droit supérieur (D.S.) et du releveur de la paupière supérieure (R.P.S.). E.C.M. indique le point d'entrée dans le cône musculaire. Remarquer la longueur du trajet libre dans le cône musculaire (C.M.). V.A. indique veine angulaire. F.S. fente sphénoïdale. S.C. sinus caverneux.

bridée par la poulie du grand oblique, qui lui fait décrire une anse concave en bas, c'est le premier point fixe au delà duquel elle reçoit souvent une racine accessoire, elle parcourt ainsi le 1/3 supérieur de l'orbite.

La veine chemine, plaquée contre le toit de l'orbite au dessus du cône musculaire, au dessus donc des releveurs et droit supérieur.

A l'union du 1/3 antérieur et du 1/3 moyen de l'orbite, la veine ophtalmique supérieure s'incline par un mouvement oblique en bas et en arrière et sur un court trajet contourne le bord latéral des releveurs et du droit supérieur, plaquée contre leur gaine, pénétrant ensuite dans le cône musculaire : c'est le 2ème point fixe.

A l'intérieur du cône, la veine se dirige en arrière et en bas, croise dans l'espace le nerf optique et sort par la fente sphénoïdale pour aboutir au pôle antérieur du sinus caverneux.

Dans son trajet elle reçoit (Fig. 2) des veines musculaires et deux veines vertiqueuses ainsi que les collatérales, rarement et incomplètement visibles.

Quelquefois on trouve individualisée une grêle veine inférieure, réunies à la veine ophtalmique supérieure par une ou plusieurs anastomoses verticales, c'est la veine ophtalmique inférieure, simple veine musculaire qui suit le plancher de l'orbite et se jette, soit dans la partie terminale de la veine ophtalmique supérieure, soit directement dans le sinus caverneux.

Quant à la veine ophtalmique moyenne, située entre ces deux veines et encore plus grêle, nous ne l'avons jamais individualisée.

Le calibre de ces veines est assez variable radiologiquement, la limite maximum normale de la veine ophtalmique supérieure est de 1,5 à 2 mm, celle de la veine ophtalmique inférieure de 1 à 1,5 mm.



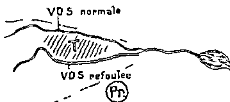


Fig 7 Cas I (Voir aussi Fig 6) Phlebogramme orbitaire de profil Les deux veines ophtalmiques superieures (V O S) etant opacifiees on voit l importance du refoulement en bas par la tumeur (T) de la veine ophtalmique superieure du cote atteint A noter de nombreux neo vaisseaux

L opacification du système veineux orbitaire controlateral semble pathologique les systemes anastomotiques souscutanes frontaux et temporaux etant generalement peu visibles la veine faciale est presque toujours bien opacifiee ainsi que le plexus ptérygoïdien reuni a celle ci et au sinus caverneux, l opacification du systeme veineux contro latéral fournit un repere comparatif excellent dans l appreciation du coté lésionnel

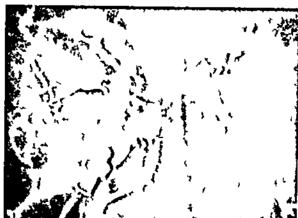
L aspect radiologique du sinus caverneux Decrit par de nombreux auteurs il est variable Il se projette sur le versant lateral de la selle turcique et prend souvent un aspect de resille vasculaire semblant perfore au centre par le contour rond de la carotide interne en particulier sur les clichés de face Parfois il n est formé que par deux ou trois veines à trajet antero postérieur sur le cliche de profil mal individualisables sur le cliche de face

Enfin rarement il n est formé que d une grosse veine de plusieurs millimetres de diametre, type de description classique des anatomistes Pour le situer sur le cliché de face il suffit de repérer les pointes des rochers il se projette juste en dedans à leur hauteur

En cas d opacification des deux systemes veineux orbitaires les deux sinus caverneux sont géneralement visibles

Chronologie des images veineuses lors de l injection A la premiere seconde la partie antérieure du systeme veineux est seule opacifiée A la deuxieme et a la troisieme seconde le systeme veineux orbitaire est entierement opacifié Le sinus caverneux parait visible de la 3ème a la 5eme seconde La persistance du produit opaque au delà de la 5eme seconde dans le systeme veineux orbito caverneux devient suspecte

Dans les tumeurs orbitaires c est entre les points fixes que se font les dé



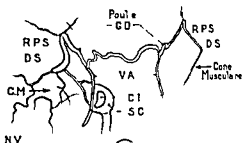


Fig. 6. Cas 1. Phlébogramme orbitaire de face injecté bilatéralement avec opacification de la communicante antérieure joignant les deux veines angulaires (V. A.). A droite l'angle supérieur du phlébogramme est fermé (inférieur à 30°), la surface du parallélogramme est très diminuée, il existe des néo-vaisseaux en dehors (N. V.). R. P. S. indique releveur de la paupière supérieure. D. S. droit supérieur. G. O. grand oblique. S. C. sinus caverneux. C. I. carotide interne. C. M. cône musculaire. (Tumeur de l'orbite extra conique.)

Phlébogramme orbitaire de face. Dans son ensemble, la veine ophtalmique de face (Fig. 3), décrit un parallélogramme ouvert en bas, compris dans le 1/3 interne de l'orbite.

Un premier segment, oblique en haut et en dehors, continue l'angulaire, fixé à l'angle supero interne de l'orbite par la poulie du grand oblique, il rejoint le bord antérieur du toit orbitaire à l'union du 1/3 moyen et du 1/3 interne. La veine change alors brusquement de direction, les deux segments formant un angle de 50 à 60°. Le deuxième segment décrit un arc concave en dehors, la veine contourne le releveur et le droit supérieur, appliquée sur l'aponévrose. Une seconde fois, la veine change de direction. Le troisième segment, toujours à l'intérieur du cone est oblique en dedans et en bas, semblant longer le bord supérieur de la fente sphénoïdale pour se jeter dans le sinus caverneux sur le versant latéral de la selle turcique.

En conclusion on peut schématiser l'image de face comme un parallélogramme à trois cotés : supéro interne et infero externe rectilignes, réunis par un cote supero externe concave en dehors, formant un angle supérieur aigu d'environ 60° ouvert en bas et un angle inférieur obtus d'environ 110°. En cas de compression tumorale, angles et aspect des cotés se modifient.

Le calibre est là encore inferieur à 2 mm mais il faut signaler que parfois les deux cotes de l'angle supérieur se superposent à son origine faisant croire à une dilatation veineuse, parfois la veine ophtalmique supérieure a un aspect dédoublé du fait d'un canal collatéral.

Les autres branches veineuses sont rarement individualisées chez le sujet normal.

males et dans la partie interne et inférieure de l orbite un croissant veineux anormal très volumineux (5 mm) De profil (Fig 9 b) sur la partie initiale de la veine ophtalmique supé rieure deux petites dilatations anévrismales mais la malformation majeure siège à la partie postérieure de l orbite elle a la forme d un tronc de cône moulé par le cone musculaire Son sommet répond juste à celui de l orbite

La sta nation du produit opaque dans la malformation nous a gêné pour le tirage du cliché négatif de soustraction la malformation reste injectée jusqu à la 13ème seconde

La pression veineuse de départ est de 15 cm pour monter à 27 après compression des jugulaires et descendre à 16 après décompression

Une autre anomalie (hors de l orbite) est à signaler c est une petite malformation veineuse mise en évidence dans le sinus maxillaire

RÉSUMÉ

La phlébo raphie semble un complément indispensable de l artériographie dans l explora tion vasculaire de l orbite En cas de tumeur elle permet de préciser le siège extra ou intra conique de la tumeur aidant le choix de la voie d abord Surtout sur les clichés de face en cas de malformation vasculaire elle a permis d expliquer la récidive des saignements intra orbitaires apres résection des portions antérieures des angiomes Elle a permis de voir que épaisses ou en résille fine ces malformations avaient toujours un pole antérieur et un pole postérieur (expliqués par l embryologie) Ceci soulève un problème de voie d abord posté rieure de la malformation très difficile non seulement a cause du siège mais du groupement à ce niveau de tout le paquet vasculo-nerveux de l orbite

SUMMARY

Phl bography would seem to be an indispensable complement to arteriography in vascular exploration of the orbit In tumor cases it gives good information regarding the extra or intraconal site of the growth and assists the choice of the way of approach Especially in frontal views in cases of vascular malformation it helped to explain recurrences of intra orbital bleeding after resection of the anterior portions of the angiomas It was possible to establi h that these malformations wheth r thick or h ir fine always had anterior and posterior poles explained by embryology) This creates a difficult problem with respect to the posterior approach to the growth not only because of the site but also because of the concentration of th whole bundle of vasculo-nervous structures of the orbit at this level

ZUSAMMENFASSUNG

Fur die Gefassuntersuchung der Orbita scheint die Phlebographie eine unerlassliche Ergänzung zur Arteriographie zu sein Bei Tumoren erhalt man gute Information über die extra oder intrakonische Ausbreitung die die Wahl des Operationsweges erleichtert Be sond rs durch Frontalprojektionen von Gefassmissbildungen trug die Untersuchung zu einer Erklarung von Rezidiven von intraorbitalen Blutungen nach Resektion der vorderen Teile der Angiome bei Es war mögl ch klarzustellen dass diese Missbildungen ob sie nun dick oder haardunn sind immer inen vorderen und hinteren Pol haben was embryologisch erklart w rden kann Es ergibt sich somit ein schwieriges Problem im Hinblick auf den Zugang zum hinteren Pol nicht nur wegen der Lage sondern auch wegen der dort befindlichen Konzen trierung von N rven und G fa.sen

En conclusion le diagnostic de tumeur maligne orbitaire sus conique fut posé et confirmé par l'histologie qui révéla un réticulo-sarcome.

Mais l'aspect de phlébogramme est différent au cours des tumeurs situées à l'intérieur du cône musculaire dont voici un exemple.

Cas 2. Neurinome orbito frontal avec envahissement du sinus caverneux. Femme de 19 ans présente un syndrome de la fente sphénoïdale avec exophtalmie, atrophie optique, atteinte des III, IV, V et VIème nerfs. Sur les clichés standard on note la destruction de la fente sphénoïdale et une opacité du sinus maxillaire droits. Sur l'artériographie une vaste tumeur fronto temporale déplaçant la cérébrale antérieure et la cérébrale moyenne, peu ou peu de déplacement de l'artère ophtalmique.

La phlébographie évocatrice surtout sur l'image de face (Fig. 8) permit d'affirmer l'existence d'une tumeur dans l'orbite, de la situer et de découvrir l'envahissement du sinus caverneux: on notait de face une ouverture des angles veineux avec élargissement du parallélogramme déformé et parcouru par d'importants néo-vaisseaux; cet aspect évoquait le siège intra conique de la tumeur.

Par ailleurs, la constatation d'une pression angulaire basse (3 cm d'eau) non modifiée par la compression jugulaire, le rétrécissement de la veine ophtalmique supérieure dans sa partie terminale avec l'absence d'injection du sinus caverneux de face et de profil, l'injection massive du système ophtalmique opposé et des collatérales sous cutanées superficielles permirent de diagnostiquer l'envahissement certain du sinus caverneux.

Toutes choses confirmées par l'examen de la pièce anatomique et l'examen histologique de ce neurinome malin envahissant le sinus caverneux.

Les malformations vasculaires veineuses

Elles restent l'une des meilleures indications de la phlébographie orbitaire.

En matière de malformation vasculaire, l'artériographie carotidienne, même par la carotide externe est souvent normale (10 fois sur 13 malades explorés). Le reste du temps, la malformation est veineuse et seule la phlébographie permet de la retrouver.

Dans l'ensemble, ces malformations veineuses sont caractérisées: 1) cliniquement par des hémorragies récidivantes dans l'orbite, intra vitréennes ou sous conjonctivales avec parfois angiome muriforme conjonctival ou palpébral, 2) radiologiquement par une hyperpression veineuse avec énorme veine ophtalmique supérieure et paquet angiomateux à deux pôles: l'un très antérieur dans l'orbite et l'autre postérieur devant la fente sphénoïdale, enfin le ralentissement de la circulation dans la malformation, l'anomalie restant injectée au delà de la sixième seconde.

Cas 3. Hématomes rétro orbitaires et intra vitréens gauches récidivants. Homme de 12 ans. Artériographie carotidienne gauche normale.

Phlébographie. Le calibre de la veine ophtalmique supérieure est quadruplé (7 mm) et les affluents de l'ophtalmique supérieure sont extrêmement visibles. De face (Fig. 9 a) il existe sur la racine supérieure de la veine ophtalmique deux petites malformations müriformes anévris

males et dans la partie interne et inférieure de l orbite un croissant veineux anormal tres volumineux (5 mm) De profil (Fig 9 b) sur la partie initiale de la veine ophtalmique supé rieure deux petites dilatations anévrismales mais la malformation majeure siege a la partie postérieure de l orbite elle a la forme d un tronc de cone moulé par le cone musculaire Son sommet répond juste a celui de l orbite

La sta nation du produit opaque dans la malformation nou a gené pour le tirage du cliché négatif de soustraction la malformation reste injectée jusqu a la 13eme seconde

La pression veineuse de départ est de 15 cm pour monter à 27 après compression des jugulaires et descendre a 16 après décompression

Une autre anomalie (hors de l orbite) est à signaler c est une petite malformation veineuse mise en évidence dans le sinus maxillaire

RÉSUMÉ

La phlébo raphie semble un complément indispensable de l artériographie dans l explora tion vasculaire de l orbite En cas de tumeur elle permet de préciser le siege extra ou intra conique de la tumeur aidant le choix de la voie d abord Surtout sur les clichés de face en cas de malformation vasculaire elle a permis d expliquer la recidive des saignements intra orbitaires après résection des portions antérieures des angiomes Elle a permis de voir que épa sses ou en résille fine ces malformations avaient toujours un pole antérieur et un pole postérieur (expliqués par l embryologie) Ceci soulève un problème de voie d abord posté rieure de la malformation tres difficile non seulement a cause du siège mais du groupement à ce niveau de tout le paquet vasculo-nerveux de l orbite

SUMMARY

Phlebography would seem to be an indispensable complement to arteriography in vascular exploration of the orbit In tumor cases it gives good information regarding the extra or intraconal site of the growth and assists the choice of he way of approach Especially in frontal views in cases of vascular malformation it helped to explain recurrences of intra orbit l bleeding after resection of the anterior portions of the angiomas It was possible to es ablish that these malformations whether thick or hair fine always had anterior and posterior poles (explained by embryology) This creates a difficult problem with respect to the posterior approach to the growth not only because of the site but also because of the concentration of th whole bundle of vasculo-nervous structures of the orbit at this level

ZUSAMMENFASSUNG

Fur d Gefassuntersuchung der Orbita scheint die Phlebographie eine unerlassliche Ergänzung zur Arteriographie zu sein Bei Tumoren erhalt man gute Information uber die extra oder Intrakonische Ausbreitung die die Wahl des Operationsweges erleichtert Be sonders durch Frontalprojektionen von Gefassmissbildungen trug die Untersuchung zu einer Erklarung von Rezidiven von intraorbitalen Blutungen nach Resektion der vorderen Teile der Angiome bei Es war moglich klarzustellen dass diese Missbildungen ob sie nun dick oder haardunn sind immer einen orderen und hinteren Pol haben was embryologisch erklart werden kann Es ergibt sich somit ein schwieriges Problem im Hinblick auf den Zugang zum h ri ren Pol nicht nur wegen der Lage sondern auch wegen der dort befindlichen Konzen tr tion von Nerven und Gefassen

En conclusion, le diagnostic de tumeur maligne orbitaire sus conique fut posé et confirmé par l'histologie qui révéla un réticulo-sarcome.

Mais l'aspect de phlébogramme est différent au cours des tumeurs situées à l'intérieur du cone musculaire dont voici un exemple.

Cas 2. Neurinome orbito frontal avec envahissement du sinus caverneux. Femme de 19 ans présente un syndrome de la fente sphénoïdale avec exophtalmie, atrophie optique, atteinte des III, IV, V et VIème nerfs. Sur les clichés standard, on note la destruction de la fente sphénoïdale et une opacité du sinus maxillaire droit. Sur l'artériographie, une vaste tumeur fronto temporale déplaçant la cérébrale antérieure et la cérébrale moyenne, peu ou peu de *déplacement de l'artère ophtalmique.*

La phlébographie, évocatrice surtout sur l'image de face (Fig. 8) permit d'affirmer l'existence d'une tumeur dans l'orbite, de la situer et de découvrir l'envahissement du sinus caverneux : on notait de face une ouverture des angles veineux avec élargissement du parallélogramme déformé et parcouru par d'importants néo vaisseaux : cet aspect évoquait le siège intra conique de la tumeur.

Par ailleurs, la constatation d'une pression angulaire basse (3 cm d'eau), non modifiée par la compression jugulaire, le rétrécissement de la veine ophtalmique supérieure dans sa partie terminale avec l'absence d'injection du sinus caverneux de face et de profil, l'injection massive du système ophtalmique opposé et des collatérales sous cutanées superficielles permirent de diagnostiquer l'envahissement certain du sinus caverneux.

Toutes choses confirmées par l'examen de la pièce anatomique et l'examen histologique de ce neurinome malin envahissant le sinus caverneux.

Les malformations vasculaires veineuses

Elles restent l'une des meilleures indications de la phlébographie orbitaire. En matière de malformation vasculaire, l'artériographie carotidienne, même par la carotide externe est souvent normale (10 fois sur 13 malades explorés). Le reste du temps, la malformation est veineuse et seule la phlébographie *permet de la retrouver.*

Dans l'ensemble, ces malformations veineuses sont caractérisées : 1) cliniquement, par des hémorragies récidivantes dans l'orbite, intra vitréennes ou *sous conjonctivales avec parfois angiome muriforme conjonctival ou palpébral,* 2) radiologiquement par une hyperpression veineuse avec énorme veine ophtalmique supérieure et paquet angiomateux à deux poles : l'un très antérieur dans l'orbite et l'autre postérieur devant la *fente sphénoïdale*, enfin le ralentissement de la circulation dans la malformation, l'anomalie restant injectée au delà de la sixième seconde.

Cas 3. Hématomes rétro orbitaires et intra vitréens gauches récidivants. Homme de 12 ans. Artériographie carotidienne gauche normale.

Phlébographie. Le calibre de la veine ophtalmique supérieure est quadruplé (7 mm) et les affluents de l'ophtalmique supérieure sont extrêmement visibles. De face (Fig. 9 a) *il existe* sur la racine supérieure de la veine ophtalmique deux petites malformations mûriformes anévris

FROM THE CENTRAL REGISTRY, STATE UNIVERSITY OF IOWA IOWA CITY IOWA,
U S A

DIAGNOSTIC VALUE AND COMPLICATIONS OF CAROTID AND VERTEBRAL ANGIOGRAPHY

by

G PERRET

The Cooperative Study of Intracranial Aneurysms and Subarachnoid Hemorrhage sponsored by the United States Public Health Service through the National Institute of Neurological Diseases and Blindness, represents the combined efforts of 19 university neurologic and neurosurgical centers in the United States and one in England It was established to study clinical and therapeutic aspects of subarachnoid hemorrhage and aneurysms The following centers participate in this study Baylor University (Houston) University of Buffalo University of California (San Francisco), Columbia University and New York Neurological Institute Cornell University and Bellevue Hospital (New York) Duke University Harvard University and Massachusetts General Hospital University of Indiana University of Iowa University of London and Atkinson Morley s Hospital University of Louisville University of Michigan University of Minnesota Mount Sinai Hospital in New York, University of Pennsylvania University of Tennessee Washington University St Louis, Wayne State University (Detroit) University of Georgia

As of June 1 1964 the Central Registry at the University of Iowa had received 5 858 cases which included 2 946 cases with intracranial aneurysms (50 3 %)

RÉFÉRENCES

BOUDET CH. Premiers résultats de la phlébographie orbitaire. Thèse Montpellier 1953—1954.
— La place du phlébogramme orbitaire dans le diagnostic des tumeurs de l'orbite. Arch. Ophtal. 15 (1955) 597.
BREGEAT P., DAVID M. et FISCHGOLD M. Exploration du sinus caverneux par phlébographie orbitaire. Bull. Soc. Ophtal. 33 (1952) 336.
DEJEAN CH., VIALLEFONT O., BOUDET CH. et PAYCHA O. Neurofibromatose de Recklinghausen à localisation orbitaire. Presse méd. 61 (1953) 80.
HENRY J. Contribution à l'étude de l'anatomie des vaisseaux de l'orbite et de la loge caverneuse (par injection de matières plastiques) du tendon de Zinn et de la capsule de Tenon. Thèse Paris 1959.
KRAYENBUHL H. The value of orbital angiography. J. Neurosurg. 19 (1962) 289.
OFFRET G., ARON ROSA D. et DHENNE D. Intérêt de l'opacification des vaisseaux dans les angiomes orbito palpébraux. Arch. Ophtal. 23 (1963) 275.
WOLFF S E. Anatomy of the eye and orbit. Lewis London 1961.

angiographies were performed with negative results 14 died and one internal carotid aneurysm was identified at autopsy If there is any suspicion that an aneurysm may be present even though the initial carotid angiograms are negative repeat angiography should be carried out for confirmation of the diagnosis especially if the angiography was done within the first four days after hemorrhage Three or four vessel angiography should routinely be carried out

Complications of angiography can be divided into local, systemic and neurologic The local complications arise at the site of vessel puncture and are directly connected with the technique of puncture and injection of contrast material The systemic complications may reflect toxicity of the contrast material and sensitivity of the patient to the contrast material The more serious complications are those arising from the central nervous system and are represented by new abnormal neurologic signs or symptoms or by aggravation of previously existing abnormal neurologic signs or symptoms An analysis of 5 669 angiographies showed that there was a total of 333 studies with immediate or delayed complications This represents an incidence of 6 05 % 4 3 % were immediate and 1 75 % were delayed However among these complications are included 31 cases of recurrent subarachnoid hemorrhage which occurred at the time of or shortly after the angiography It is very doubtful that the subsequent subarachnoid hemorrhage in a patient who has had such hemorrhages before and has an aneurysm is a true complication of angiography It may represent the natural course of the initial disease In our studies there were 363 carotid angiographic studies performed in patients who had aneurysms but who never bled In none of these cases was carotid angiography followed by a subarachnoid hemorrhage Thus if the subsequent subarachnoid hemorrhage was discarded the incidence of true angiographic complications is 5 5 % The complications included transient hemiparesis in 1 4 % of the cases permanent hemiparesis in 0 5 % convulsions in 0 5 % and severe neck hematoma in 0 5 %

A study of complications in various age groups showed that there were twice as many complications after the age of 60 as before the age of 20 but only in patients who have ruptured aneurysms Age had little influence on the complications of angiography in the presence of subarachnoid hemorrhage not caused by ruptured aneurysm The nature of the contrast material had little influence on the complications except for thorotrast which produced six complications in 30 cases Thorotrast may have been used in patients in poor condition or known to be allergic to other media

Analysis of the incidence and nature of angiographic complications in relation to the number of injections or to the amount of contrast material

452 cases of arteriovenous anomalies (7.7 %), and 58 cases with both aneurysm and arteriovenous anomaly (0.99 %). There were 2 402 cases of subarachnoid hemorrhage not due to aneurysm or arteriovenous anomalies (41 %) and 521 cases of non bleeding aneurysm or arteriovenous anomaly. The site of single aneurysm was on the internal carotid artery in 44.3 %, anterior communicating region in 29.1 %, middle cerebral artery in 19 %, pericallosal artery 2.3 % and posterior portion of the circle of Willis in 5.3 % of cases. The incidence of multiple aneurysms as disclosed by angiography was 15 %, while in a series of 644 autopsies, multiple aneurysms were found in 23 % of cases. Sixteen per cent had two aneurysms, 4.2 % three aneurysms and 2.6 % four or more aneurysms.

The angiographic studies were carried out under local anesthesia in 78 % of cases and under general anesthesia in 22 %. Hypaque was the contrast material used in 90 % of the cases. The number of injections varied greatly between one and nine, and the volume of injected contrast material varied between one and 101 ml.

The question has frequently been raised as to whether there is any relationship between the demonstration of the aneurysm and the time interval between the subarachnoid hemorrhage and angiography. It has been postulated that vascular spasm and other alterations in cerebral circulation immediately after subarachnoid hemorrhage may result in an aneurysm not becoming filled with contrast medium if angiography is performed too soon. In our study, bilateral carotid angiography was carried out within the first seven days after hemorrhage in 66 % of the cases and within two weeks after hemorrhage in 80 % of the cases. On the basis of 4 364 angiographies carried out at various intervals after the bleeding episode from one day to over 30 days, an aneurysm could be demonstrated in 45.5 %. The incidence did not vary more than ± 4.5 %, suggesting that the time of angiography in relation to hemorrhage has no significant effect on the chances of demonstrating aneurysm if one is present.

In 993 cases which failed to reveal an aneurysm or arteriovenous malformation after subarachnoid hemorrhage on initial bilateral carotid angiography, further carotid angiography was performed in 158 cases and revealed, in 35 cases, an aneurysm of the carotid system presumably undetected in the first examinations. This represents a 3.5 % false negative report on initial bilateral carotid angiography. A comparison of this figure with autopsy findings is of interest. One hundred and five patients with negative bilateral carotid angiographic findings died and post mortem examination revealed the presence of an aneurysm in 26: 12 on the anterior communicating, 3 on the middle cerebral, 2 on the anterior cerebral, 2 on the internal carotid artery and 7 on the vertebral basilar circulation. Of a series of cases in whom two carotid

angiographies were performed with negative results 14 died and one internal carotid aneurysm was identified at autopsy If there is any suspicion that an aneurysm may be present even though the initial carotid angiograms are negative repeat angiography should be carried out for confirmation of the diagnosis especially if the angiography was done within the first four days after hemorrhage Three or four vessel angiography should routinely be carried out

Complications of angiography can be divided into local systemic and neurologic The local complications arise at the site of vessel puncture and are directly connected with the technique of puncture and injection of contrast material The systemic complications may reflect toxicity of the contrast material and sensitivity of the patient to the contrast material The more serious complications are those arising from the central nervous system and are represented by new abnormal neurologic signs or symptoms or by aggravation of previously existing abnormal neurologic signs or symptoms An analysis of 5 669 angiographies showed that there was a total of 333 studies with immediate or delayed complications This represents an incidence of 6 05 % 4 3 % were immediate and 1 75 % were delayed However among these complications are included 31 cases of recurrent subarachnoid hemorrhage which occurred at the time of or shortly after the angiography It is very doubtful that the subsequent subarachnoid hemorrhage in a patient who has had such hemorrhages before and has an aneurysm is a true complication of angiography It may represent the natural course of the initial disease In our studies there were 363 carotid angiographic studies performed in patients who had aneurysms but who never bled In none of these cases was carotid angiography followed by a subarachnoid hemorrhage Thus if the subsequent subarachnoid hemorrhage was discarded the incidence of true angiographic complications is 5 5 % The complications included transient hemiparesis in 1 4 % of the cases permanent hemiparesis in 0 5 % convulsions in 0 5 % and severe neck hematoma in 0 5 %

A study of complications in various age groups showed that there were twice as many complications after the age of 60 as before the age of 20 but only in patients who have ruptured aneurysms Age had little influence on the complications of angiography in the presence of subarachnoid hemorrhage not caused by ruptured aneurysm The nature of the contrast material had little influence on the complications except for thorotrast which produced six complications in 30 cases Thorotrast may have been used in patients in poor condition or known to be allergic to other media

Analysis of the incidence and nature of angiographic complications in relation to the number of injections or to the amount of contrast material

injected showed no direct relationship with either factor The incidence of complications seemed to be higher *in the patients who were examined under* general anesthesia as compared to those examined under local anesthesia Under general anesthesia, the rate of immediate and delayed complications was increased and so was the rate of permanent hemiparesis Interestingly enough, the rate of convulsions was the same (0 5 %) It seems that the complication rate from angiography is not influenced by the patient's state of responsiveness at the time of the study However, it was interesting to note *that the incidence of convulsion was lower in the alert patient than in the* patient with disturbances of responsiveness The patient's pre angiographic neurologic status did not seem to influence the rate of complications

The incidence of complications is greater in the presence of subarachnoid hemorrhage Of the patients examined angiographically after their first bleeding episode, those with neither aneurysm nor arteriovenous anomalies had a lower incidence of complication than those who had an aneurysm *Patients who had an aneurysm* or arteriovenous anomaly *but who had not* had a subarachnoid hemorrhage showed an even lower complication rate Most patients having a ruptured aneurysm had a higher complication rate during the first two weeks following hemorrhage than when the study was done at a later date This may suggest that angiography may add an additional insult to an already impaired cerebral circulation

Complications from postoperative angiography were higher in patients *who were treated with* carotid *ligation than in those treated by an intracranial* operation, 5 1 % and 2 2 % respectively This may again be directly related to the disturbance in cerebral circulation and the increased impairment of circulation produced by angiography

The incidence of fatal angiographic complications is difficult to assess Arbitrarily, it was considered that any death occurring within 24 hours of angiography or due to permanent complications should be included In a *group of 3 972 patients who were studied by angiography*, 39 died during or after angiography, representing a gross mortality rate of 0 98 % If, however, one excludes rebleeding from angiographic complications, the mortality rate directly related to the angiographic procedure was 0 6 % Thirteen patients had a proven recurrent hemorrhage and died six bled during the procedure, and seven bled after completion of the procedure Seven patients who were moribund prior to angiography died during or shortly after the examination *Three patients became suddenly unresponsive* during the procedure and died 1, 2 and 18 days later without regaining consciousness and without recurrent hemorrhage Four patients developed a hemiplegia during angiography and died within 24 hours Two patients became hemiplegic after completion of the

procedure, one died within 24 hours and was found to have a thrombotic occlusion of the basilar artery after vertebral angiography had been done The other died six days later Three patients developed a cervical hematoma requiring tracheostomy and died within 24 hours One of these patients had a gross hematoma tracking down into the mediastinum One patient had a convulsion during the angiography and died three days later One patient became hypotensive and died suddenly three hours later Three patients progressively deteriorated dying within five days, one was shown at autopsy to have a dissecting aneurysm of the common carotid artery Two patients who had angiography performed under general anesthesia were hemiplegic and aphasic on awakening and both died within three days

Conclusion A total of 5 685 angiographic studies performed upon 3 972 patients have been analyzed The incidence of aneurysms missed in the usual bilateral carotid angiograms points out the need for repeated examination (at angiography) including the vertebral basilar system Study of the complications does not allow us to make any specific recommendations as no factors have been proven to be significantly related to the complications

The final report based on 7 932 angiographies is published in the Journal of Neurosurgery July 1966

SUMMARY

A report is presented on 2 946 cases with intracranial aneurysms or vascular anomalies with special emphasis on statistical distribution angiographic demonstrability and complication risks.

ZUSAMMENFASSUNG

Es wird uber 2 946 Falle mit intrakraniellen Aneurysmen oder Gefässmissbildungen berichtet wobei der statistischen Verbreitung angiographischen Darstellbarkeit und den Komplikationsrisikos besondere Beachtung geschenkt wird

RÉSUMÉ

Présentation de 2 946 cas d anévrismes intracraniens ou anomalies vasculaires avec étude particulière de leur distribution statistique de la possibilité de les mettre en évidence par angiographie et des risques de complications

injected showed no direct relationship with either factor The incidence of complications seemed to be higher in the patients who were examined under general anesthesia as compared to those examined under local anesthesia Under general anesthesia, the rate of immediate and delayed complications was increased and so was the rate of permanent hemiparesis Interestingly enough, the rate of convulsions was the same (0 5 %) It seems that the complication rate from angiography is not influenced by the patient's state of responsiveness at the time of the study However, it was interesting to note that the incidence of convulsion was lower in the alert patient than in the patient with disturbances of responsiveness The patient s pre angiographic neurologic status did not seem to influence the rate of complications

The incidence of complications is greater in the presence of subarachnoid hemorrhage Of the patients examined angiographically after their first bleeding episode, those with neither aneurysm nor arteriovenous anomalies had a lower incidence of complication than those who had an aneurysm Patients who had an aneurysm or arteriovenous anomaly but who had not had a subarachnoid hemorrhage showed an even lower complication rate Most patients having a ruptured aneurysm had a higher complication rate during the first two weeks following hemorrhage than when the study was done at a later date This may suggest that angiography may add an additional insult to an already impaired cerebral circulation

Complications from postoperative angiography were higher in patients who were treated with carotid ligation than in those treated by an intracranial operation, 5 1 % and 2 2 % respectively This may again be directly related to the disturbance in cerebral circulation and the increased impairment of circulation produced by angiography

The incidence of fatal angiographic complications is difficult to assess Arbitrarily, it was considered that any death occurring within 24 hours of angiography or due to permanent complications should be included In a group of 3 972 patients who were studied by angiography, 39 died during or after angiography, representing a gross mortality rate of 0 98 % If, however, one excludes rebleeding from angiographic complications, the mortality rate directly related to the angiographic procedure was 0 6 % Thirteen patients had a proven recurrent hemorrhage and died, six bled during the procedure, and seven bled after completion of the procedure Seven patients who were moribund prior to angiography died during or shortly after the examination Three patients became suddenly unresponsive during the procedure and died 1, 2 and 18 days later without regaining consciousness and without recurrent hemorrhage Four patients developed a *hemiplegia during angiography* and died within 24 hours Two patients became hemiplegic after completion of the

procedure one died within 24 hours and was found to have a thrombotic occlusion of the basilar artery after vertebral angiography had been done The other died six days later Three patients developed a cervical hematoma requiring tracheostomy and died within 24 hours One of these patients had a gross hematoma tracking down into the mediastinum One patient had a convulsion during the angiography and died three days later One patient became hypotensive and died suddenly three hours later Three patients progressively deteriorated dying within five days one was shown at autopsy to have a dissecting aneurysm of the common carotid artery Two patients who had angiography performed under general anesthesia were hemiplegic and aphasic on awakening and both died within three days

Conclusion A total of 5 685 angiographic studies performed upon 3 972 patients have been analyzed The incidence of aneurysms missed in the usual bilateral carotid angiograms points out the need for repeated examination (at angiography) including the vertebral basilar system Study of the complications does not allow us to make any specific recommendations as no factors have been proven to be significantly related to the complications

The final report based on 7 93? angiographies is published in the Journal of Neurosurgery July 1966

SUMMARY

A report is presented on 2 946 cases with intracranial aneurysms or vascular anomalies with special emphasis on statistical distribution angiographic demonstrability and complication risks

ZUSAMMENFASSUNG

Es wird uber 2 946 Falle mit intrakraniellen Aneurysmen oder Gefassmissbildungen berichtet wobei der statistischen Verbreitung angiographischen Darstellbarkeit und den Komplikationsrisikos besondere Beachtung geschenkt wird

RÉSUMÉ

Présentation de 2 946 cas d anévrismes intracraniens ou anomalies vasculaires avec étude particulière de leur d stribution statistique de la possibilité de les mettre en évidence par angiographie et des risques de complications

FROM THE DEPARTMENT OF RADIOLOGY, ST VINCENT'S HOSPITAL AND MEDICAL CENTER, NEW YORK, U S A

TRANSAXILLARY SELECTIVE CATHETERIZATION OF THE CAROTID AND VERTEBRAL ARTERIES

by

PLINIO ROSSI

The axillary approach to arterial catheterization is a recent advent in angiography With the advance of medical techniques and improved specialized equipment such as catheters, guide wires, pressure injectors, and image intensification, angiography has become increasingly important as a diagnostic aid

Most techniques used to inject contrast medium into the aortic arch and its branches with a single injection result in a suboptimal demonstration of the intracerebral vessels This is due to the excessive dilution of the contrast medium within the aorta and brachiocephalic trunk In addition, simultaneous contrast filling of all the vessels of the head results in superimposition of the arteries with loss of valuable information

To overcome these shortcomings, we have used a technique whereby, through a single puncture of the axillary artery the major vessels of the neck may be demonstrated and then selectively catheterized for completion of the study of the intracerebral circulation (Figs 2, 3 4 and 5) The entire examination is performed without additional punctures of the other arteries leading to the head

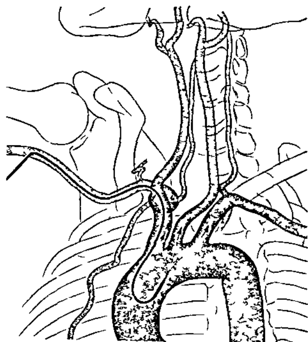


Fig 1 Transaxillary catheterization of the aortic arch Arrows indicate the direction in which the catheter may be advanced for selective contrast injection into the major vessels in the neck

This angiographic technique is based upon the use of a specially shaped catheter similar to one described by AMPLATZ et coll (1963) and a modified Seldinger wire

The catheter is made of radio opaque polyethylene approximately 50 cm in length with a U shaped tapered tip This catheter is shaped by taking a conventional red Kifa inserting a guide wire and heating the tip over an alcohol flame Gradual tension results in a narrowing of the lumen of the catheter so that the inner diameter of the heated section becomes that of the guide wire Once the tip is formed the excess is cut off and the catheter with the wire still within its lumen is immersed in very hot water and the tip bent into a loop It is then plunged into cold water so that the present shape will be permanent One additional hole is made at the side of the catheter 1 cm from the end hole to allow easy flow of contrast medium and avoid recoil

The Seldinger guide wire is modified by partial removal of its core so that its flexible tip is increased to about 6 inches in length This modified guide wire we have named floppy wire because of its long flexible end

FROM THE DEPARTMENT OF RADIOLOGY, ST VINCENT'S HOSPITAL AND MEDIC
CENTER, NEW YORK, U S A

TRANSAXILLARY SELECTIVE CATHETERIZATION OF THE CAROTID AND VERTEBRAL ARTERIES

by

PLINIO ROSSI

The axillary approach to arterial catheterization is a recent advent angiography With the advance of medical techniques and improved speciali equipment such as catheters, guide wires pressure injectors, and im intensification, angiography has become increasingly important as a diagno aid

Most techniques used to inject contrast medium into the aortic arch and branches with a single injection result in a suboptimal demonstration of intracerebral vessels This is due to the excessive dilution of the contrast medi within the aorta and brachiocephalic trunk In addition, simultaneous cont filling of all the vessels of the head results in superimposition of the arte with loss of valuable information

To overcome these shortcomings, we have used a technique where through a single puncture of the axillary artery the major vessels of the n may be demonstrated and then selectively catheterized for completion of study of the intracerebral circulation (Figs 2, 3, 4 and 5) The entire exami tion is performed without additional punctures of the other arteries leadin

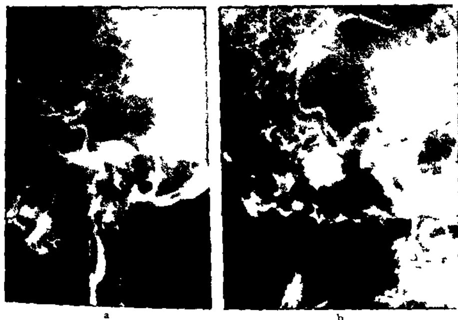


Fig 4 Lateral projection (a) and oblique projection (b) Arterial phase Good demonstration of the intracerebral vessels

undesired arteries If no obstruction is met the wire is advanced into the ascending aorta and the U shaped catheter then slipped over the wire which is subsequently removed If the wire cannot be advanced due to tortuosity arteriosclerotic plaques or abnormal position of the mouth of the vertebral or other arteries the floppy wire is then used

The use of a long flexible tip has proven to be a considerable aid in traversing these obstacles This can be done because the tip of the floppy wire becomes anchored at the outer wall of a bend in the artery and the flexible portion loops on itself and follows the lumen of the tortuous artery acting as a new tip which has already passed the site of temporary obstruction without applying any direct pressure on the obstacle

When the catheter is finally placed within the aorta and the wire withdrawn the catheter tip will return to its preformed U shape (see Fig 1) As can be seen from the figure the tip of the catheter is now pointing at the orifice of the major arteries arising from the aortic arch and by proper manipulation the tip can be made to enter the selected artery This is accomplished by slow withdrawal of the catheter trying to hook the tip in the mouth of the artery If technical difficulties prevent proper placement of the catheter the floppy





Fig 2 a) The flexible portion of the wire has entered the right common carotid artery Position of wire indicates the artery entered b) Following removal of the wire a test injection is made to control the position of the tip of the catheter

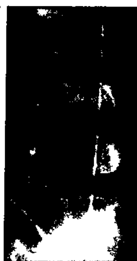




Fig 3 a) The flexible portion of the wire has entered the left common carotid artery b) Following removal of the wire and control injection the artery is clearly demonstrated

Method

The patient is sedated with 100 mg of Pentobarbital sodium (Seconal)® given one hour before the procedure and 50 mg of Meperidine hydrochloride (Demerol)® and atropine sulphate 0 4 mg just prior to transfer to the roentgen department

For the examination, the patient is placed on the radiographic table in a minimal degree of right posterior oblique position with the selected arm abducted 90 degrees and externally rotated The elbow is flexed and the hand supported by a foam rubber pad This position is used to open the aortic arch so as to identify the anatomic structures and tip of the catheter under fluoroscopy Although this technique has been used with both conventional fluoroscopy and image intensification, it is found that in heavy patients identification of the position of the tip of the catheter is very difficult without image intensification The right axillary approach is usually selected as it facilitates ease of the examination

Careful palpation of the axilla is made to determine the site of maximum pulsation and course of the axillary artery The skin is then entered approximately 2 cm from the outer margin of the great pectoralis muscle

After puncturing the artery with the needle a Seldinger wire is advanced into the artery and its passage observed under fluoroscopy to avoid entering

4 Using this remote portal of entry, it is safe to place the catheter in the mouth of a major vessel when marked narrowing or occlusion of the other vessel is present

5 The floppy wire has less chance of displacing an atheromatous plaque

6 Multiple arterial punctures of the neck are obviated when panangiography is required

7 Superimposition of vessels is avoided since only a single artery is filled with contrast medium at one time

8 Excellent filling of the intracranial vessels is obtained (Fig 4)

9 Rate of filling of both sides of the head may be compared since the contrast enters from the arch of the aorta

10 The arteries of the neck are not compromised since the vessels are not punctured

11 Radial pulse is usually preserved during and after the procedure

12 There is much less discomfort to the patient

13 A long and tortuous femoral artery course is obviated

Results

Thirty five cases have been examined using this technique In 65 % of the cases successful results were obtained A successful result is defined as contrast filling of the aortic arch and major arteries of the neck and of the intracerebral vessels On occasion spasm of the vessels has prevented a successful completion of the study

In two cases, the left vertebral artery arose from the aortic arch and in one case the left common carotid artery was occluded

In one case the radial pulse was absent for 2 days and petechial hemorrhages appeared on the arm

SUMMARY

This paper presents a study of selective catheterization of the vessels leading to the head using a single arterial puncture the axillary artery Techniques are described for shaping catheters and guide wire to facilitate the selective catheterization Results and advantages are discussed

ZUSAMMENFASSUNG

Es wird uber eine Studie von selektiver Katheterisierung der Gefasse des Kopfes mittels einfacher Punktion der art axillaris berichtet Es wird die Technik der Formung des Katheters und Fuhrungsdrahtes zwecks Erleichterung der selektiven Katheterisierung wird beschrieben Ergebnisse und Vorteile der Methode werden besprochen



Fig 5 Lateral projection of the vertebral artery arterial phase The catheter was advanced from left axillary artery into left vertebral artery for several centimeters

wire is then reintroduced until its tip extends beyond the catheter end Due to the flexibility of the wire the catheter shape is not disturbed and the tip of the wire will point in the same direction as the catheter

By combining manipulation of the catheter and wire, the tip of the wire can usually be placed in the desired position The position of the tip indicates the artery entered (Figs 2 and 3) Once the wire is in place, the catheter can then be introduced by following the leading wire

The wire is then withdrawn and 5 ml of contrast medium injected through the catheter to verify its position (Figs 2 and 3) If placement is correct, 12 ml of contrast medium are injected by hand or by pressure injection at low pressure to demonstrate the intracranial portion of the artery and the study is carried out in the usual fashion (Figs 4 and 5)

Advantages of the method

1 Using a single puncture, the arch of the aorta and its major branches may be filled with contrast medium

2 Without removing the catheter, selective contrast filling of each of the major vessels leading to the head may be obtained

3 Tortuous vessels may be negotiated using the 'floppy wire

4 Using this remote portal of entry it is safe to place the catheter in the mouth of a major vessel when marked narrowing or occlusion of the other vessel is present

5 The floppy wire has less chance of displacing an atheromatous plaque

6 Multiple arterial punctures of the neck are obviated when panangiography is required

7 Superimposition of vessels is avoided since only a single artery is filled with contrast medium at one time

8 Excellent filling of the intracranial vessels is obtained (Fig 4)

9 Rate of filling of both sides of the head may be compared since the contrast enters from the arch of the aorta

10 The arteries of the neck are not compromised since the vessels are not punctured

11 Radial pulse is usually preserved during and after the procedure

12 There is much less discomfort to the patient

13 A long and tortuous femoral artery course is obviated

Results

Thirty five cases have been examined using this technique In 65 % of the cases successful results were obtained A successful result is defined as contrast filling of the aortic arch and major arteries of the neck and of the intracerebral vessels On occasion spasm of the vessels has prevented a successful completion of the study

In two cases the left vertebral artery arose from the aortic arch and in one case the left common carotid artery was occluded

In one case the radial pulse was absent for 2 days and petechial hemorrhages appeared on the arm

SUMMARY

This paper presents a study of selective catheterization of the vessels leading to the head using a single arterial puncture the axillary artery Techniques are described for shaping catheters and guide wire to facilitate the selective catheterization Results and advantages are discussed

ZUSAMMENFASSUNG

Es wird uber eine Stud e von selektiver Katheterisierung der Gefässe des Kopfes mittels einfacher Punktion der art axillaris berichtet Es wird die Technik der Formung des Katheters und Fuhrungsdrahtes zwecks Erleichterung der selektiven Katheterisierung wird beschrieben Ergebnisse und Vorteile der Methode werden besprochen



Fig 3 Lateral projection of the vertebral artery arterial phase The catheter was advanced from left axillary artery into left vertebral artery for several centimeters

wire is then reintroduced until its tip extends beyond the catheter end Due to the flexibility of the wire the catheter shape is not disturbed and the tip of the wire will point in the same direction as the catheter

By combining manipulation of the catheter and wire, the tip of the wire can usually be placed in the desired position The position of the tip indicates the artery entered (Figs 2 and 3) Once the wire is in place, the catheter can then be introduced by following the leading wire

The wire is then withdrawn and 5 ml of contrast medium injected through the catheter to verify its position (Figs 2 and 3) If placement is correct, 12 ml of contrast medium are injected by hand or by pressure injection at low pressure to demonstrate the intracranial portion of the artery and the study is carried out in the usual fashion (Figs 4 and 5)

Advantages of the method

1 Using a single puncture, the arch of the aorta and its major branches may be filled with contrast medium

2 Without removing the catheter, selective contrast filling of each of the major vessels leading to the head may be obtained

3 Tortuous vessels may be negotiated using the 'floppy wire

CLINICA NEUROCHIRURGICA DELL'UNIVERSITA DI PADOVA (DIRETTORE PROF F FRUGONI) ITALIA

CONSIDERATIONS RADIOLOGIQUES DANS LES NEURINOMES DU GANGLION DE GASSER

par

R RUBERTI F GALLIGIONI et A CARTERI

Les neurinomes du ganglion de GASSER sont des tumeurs rares, tout au moins si on compare leur frequence a celle des tumeurs du nerf acoustique Depuis les descriptions de plusieurs auteurs leur symptomatologie est bien connue Il s agit de tumeurs a evolution tres lente qui se traduisent pendant longtemp par des algies faciales

Toutefois la seule clinique est tres souvent insuffisante pour le diagnostic de ces tumeurs tandis que l etude radiologique peut nous aider considérablement a resoudre ce probleme

L étude radiologique de ces malades a eté fondee dans le passe surtout sur l examen standard et sur la pneumographie on n a pas suffisamment souligne par contre, a notre avis l importance que l angiographie carotidienne et vertébrale peuvent avoir dans le diagnostic de ces tumeurs

C est pour cela que nous croyons utile de faire quelques considerations radiologiques basees soit sur les donnees de la litterature soit sur 6 cas de neurinome du ganglion du GASSER controlés chirurgicalement a la Clinique Neuro-Chirurgicale de Padoue Dans nos 6 cas il s agissait de tumeurs à siege exclusivement ou surtout extra dural 2 strictement limitees a la fosse cérébrale

RÉSUMÉ

Présentation d une étude du cathétérisme sélectif des arteres céphaliques par une seule ponction artérielle de l artere axillaire Description de la technique pour donner aux cathéters et au fil guide la forme qui facilite le cathétérisme sélectif et discussion des résultats et des avantages

REFERENCES

AMPLATZ K and HARNER R A new subclavian catheterization technic Radiology 78 (1962) 693

— RESCH J and HILSI S A catheter approach for cerebral angiography Radiology 81 (1963) 675

BAUM S and ABRAMS H I A J shaped catheter for retrograde catheterization of tortuous vessels Radiology 83 (1964) 430

BERG D VAN DEN et coll Vertebrobasilar angiography via catheterization of the brachial artery Ned T Geneesk 107 (1963) 174

FEOIRFIEL J et coll Vertebral arteriography by axillary route Preliminary results in vascular syndromes of the brain stem Ann Radiol 7 (1964) 189

GORFF J A TINDALL G T and ODOM J L Percutaneous retrograde brachial angiography in the diagnosis of acoustic neurinoma — Results in 4 cases Amer J Roentgenol 92 (1964) 829

HANAFEE W Axillary artery approach to carotid vertebral abdominal aorta and coronary angiography Radiology 81 (1963) 559

HAUGE I Catheter vertebral angiography Acta radiol Suppl No 109 (1964)

HOWLAND W J and CURRY J L Transient cerebral blindness — A hazard of vertebral artery catheterization Radiology 83 (1964) 428

KLAMUT M CZOCHRA M BRYS S and ZDERKIEWICZ E A technique for right vertebral arteriography with the aid of carotid catheterization Neurol Neurochir Psychiat pol 12 (1962) 699

MARSHALL T R LING J T and GONZALES P Additional experience with direct percutaneous noncatheter bronchial angiography — left panarteriography — right cerebral angiography Radiology 81 (1963) 568

MULLER R GREITZ I LILIFQUIST B and HELLSTROM L Aortocervical angiography in occlusive cerebrovascular disease Neurology 14 (1964) 136

NEWTON T R The axillary artery approach to arteriography of the aorta and its branches Amer J Roentgenol 89 (1963) 275

PYGOTT F and HUTTON C F Vertebral arteriography by percutaneous brachial artery catheterization Brit J Radiol 32 (1959) 114

RADNER S Vertebral angiography by catheterization New method employed in 221 cases Acta radiol Suppl No 87 (1951)

RIVERA R and PEDROTE J A Bilateral vertebral angiography by one contrast injection J cardiovasc Surg 4 (1963) 101

ROY P Percutaneous catheterization of the axillary artery New route of approach for carotid and vertebral arteriography Roentgen Europ 6 (1963) 122

SCOTT M HURTAGH I LAPAYOWKER M and BAIRD M Vertebral basilar and carotid angiography by injection of brachial artery Amer J Roentgenol 90 (1963) 546



Fig 3 Artériographie vertébrale droite dans un autre cas de neurinome du ganglion de Gasser droit à développement sus et sous tentoriel comme le montre pour ce qui concerne l'expansion sous tentorielle le déplacement considérable de l'artère basilaire et de ses branches

moyenne 4 a développement prédominant dans la fosse cérébrale moyenne mais avec une expansion sous tentorielle

En ce qui concerne l'examen radiographique standard le signe le plus typique que nous avons observé dans tous nos cas et dans plusieurs cas de la littérature est sûrement constitué par la lyse à contours nets du bord supérieur du rocher au niveau de la fossette du ganglion de GASSER lyse qui peut arriver suivant l'expansion de la tumeur jusqu'à la destruction de toute la partie interne du rocher L'ostéolyse de ces structures donne lieu naturellement à la typique image de l'élargissement du trou déchiré antérieur par érosion des bords interne et externe du trou lui même Tout à fait exceptionnels sont l'élargissement des trous ovale et grand rond la lyse des clinoïdes postérieures et des autres structures qu'on peut en réalité trouver dans les neurinomes très volumineux, mais qui n'ont aucun caractère d'utilité diagnostique Les données de l'examen standard peuvent pourtant fournir une première orientation dans le diagnostic

Pour ce qui concerne l'examen pneumographique il permet d'avoir des renseignements précis sur l'expansion de la tumeur mais ne donne aucune information utile au point de vue de sa nature car il permet très difficilement d'établir le siège intra ou extra dural de la lésion

C'est incontestablement l'artériographie carotidienne qui constitue de loin l'examen le plus instructif car ses données sont à la fois riches et précises

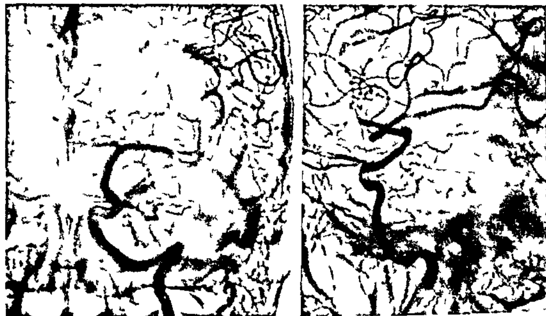


Fig 1 Artériographie carotidienne gauche Déformation du segment extra dural de la carotide interne particulièrement evident dans la projection antéro postérieure



Fig 2 Figures schématiques reproduisant la déformation du segment extra dural de la carotide interne dans les neurinomes du ganglion de Gasser Le déplacement est caractéristique et permet le diagnostic du siège et de la nature de la lésion

etc) et veineux indiquent seulement l expansion reelle de la tumeur dans la fosse cérebrale moyenne

Dans les tumeurs qui ont une expansion sous tentorielle l angiographie vertebrale peut fournir des renseignements precis En effet le deplacement eventuel du segment superieur de l artere basilaire est pathognomonique de l expansion sous tentorielle de la tumeur (Fig 3) tandis que le soulevement de l artere cerebrale posterieure ne l indique pas avec certitude (Fig 4)

En conclusion le diagnostic de neurinome du ganglion de GASSER peut souvent etre affirmé radiologiquement L atteinte caracteristique du rocher et le deplacement du segment extra dural de la carotide interne ont une valeur diagnostique précieuse

RÉSUMÉ

Cette étude radiologique est basée sur 6 cas de neurinome du ganglion de Gasser vérifiés chirurgicalement Les auteurs soulignent en particulier l utilite de l arteriographie carotidienne pour le diagnostic de l expansion extra durale de la tumeur et de l artériographie vertébrale pour le diagnostic de son extension sous tentorielle

SUMMARY

Some radiological aspects of six cases of surgically verified neurinomas of the gasserian ganglion have been studied The importance of carotid angiography in regard to the extra dural extension of these lesions and of vertebral angiography in regard to the subtentorial extension is stressed

ZUSAMMENFASSUNG

Einige rontgenclogische Gesichtspunkte von sechs chirurgisch verifizierten Neurinomen des Ganglion Gasseri werden mitgeteilt Der Wert der Carotisangiographie bei extraduraler Ausbreitung und die Wichtigkeit der Vertebralisangiographie bei subtentorieller Ausbreitung solcher Veranderungen wird hervorgehoben

BIBLIOGRAPHIE

BERNASCONI V Caratteristiche radiologiche dei processi espansivi extradurali del pavimento della fossa cranica media Radiol med (Torino) 45 (1959) 725

KRAYENBUHL H Das Neurinom des Nervus Trigeminus Bull schweiz Akad med Wiss 15 (1959) 89

LINDGREN E Das Rontgenbild bei Tumoren des Ganglion Gasseri Acta chir scand 85 (1941 181

TONNIS W und PIA H W Die Geschwulste der mittleren Schadelgrube in Arteriogramm Zbl Neurochir 12 (1952) 145

RUBERTI R Considerazioni angiografiche su un caso di tumore parasellare extradurale Riv Anat pat 10 (1955) 196

WETTBERG G Angiographic changes in neurinoma of the trigeminal nerve Acta radiol I D (1963) 513



Fig. 4. Artériographie vertébrale gauche dans un troisième cas de neurinome du ganglion de Gasser gauche développé exclusivement dans la fosse cérébrale moyenne. Le soulèvement de l'artère cérébrale postérieure est modéré et n'indique pas avec certitude une expansion sous-tentorielle de la tumeur.

L'artériographie carotidienne montre l'extension extra-durale de la tumeur par le déplacement caractéristique du segment extra-dural de la carotide interne (Fig. 1), déplacement qui est complètement différent de ceux provoqués par d'autres tumeurs extra-durales de la même région (ostéochondrome, sarcome, kyste épidermoïde, etc.). Alors que les autres tumeurs extra-durales de la fosse cérébrale moyenne donnent un déplacement en haut et en dedans du segment extra-dural de la carotide interne, les neurinomes du ganglion de GASSER déplacent le même segment artériel en bas et en dedans. Ce déplacement artériel caractéristique déterminé par les neurinomes du ganglion de GASSER est mieux compréhensible si l'on considère la situation anatomique particulière du ganglion lui-même et la modalité d'expansion de la tumeur par rapport aux structures ostéo-durales et vasculaires contiguës. Le siphon carotidien, au niveau du trou déchiré antérieur et dans son trajet extra-dural, semble délimiter en dedans et en bas la tumeur située à la pointe du rocher (Fig. 2).

Les déplacements des autres segments artériels (artère cérébrale moyenne,

etc) et veineux indiquent seulement l expansion reelle de la tumeur dans la fosse cerebrale moyenne

Dans les tumeurs qui ont une expansion sous tentorielle l angiographie vertebrale peut fournir des renseignements precis En effet le déplacement eventuel du segment superieur de l artere basilaire est pathognomonique de l expansion sous tentorielle de la tumeur (Fig 3) tandis que le soulevement de l artere cerebrale posterieure ne l indique pas avec certitude (Fig 4)

En conclusion, le diagnostic de neurinome du ganglion de GASSER peut souvent etre affirme radiologiquement L atteinte caracteristique du rocher et le deplacement du segment extra dural de la carotide interne ont une valeur diagnostique precieuse

RÉSUMÉ

Cette étude radiologique est basée sur 6 cas de neurinome du ganglion de Gasser vérifiés chirurgicalement Les auteurs soulignent en particulier l utilité de l artériographie carotidienne pour le diagnostic de l expansion extra-durale de la tumeur et de l artériographie vertébrale pour l diagnostic de son extension sous tentorielle

SUMMARY

Some radiological aspects of six cases of surgically verified neurinomas of the gasserian ganglion have been studied The importance of carotid angiography in regard to the extra dural extension of these lesions and of vertebral angiography in regard to the subtentorial extension is stressed

ZUSAMMENFASSUNG

Einige röntgenologische Gesichtspunkte von sechs chirurgisch verifizierten Neurinomen des Ganglion Gasseri werden mitgeteilt Der Wert der Carotisangiographie bei extraduraler Ausbreitung und die Wichtigkeit der Vertebralisangiographie bei subtentorieller Ausbreitung solcher Veranderungen wird hervorgehoben

BIBLIOGRAPHIE

BERNASCONI V Caratteristiche radiologiche dei processi espansivi extradurali del pavimento della fossa cranica media Radiol med (Torino) 45 (1959) 725

KRAYENBÜHL H Das Neurinom des Nervus Trigeminus Bull schweiz Akad med Wiss 15 (1959) 89

LINDGREN E Das Rontgenbild bei Tumoren des Ganglion Gasseri Acta chir scand 85 (1941) 181

TÖNNIS W und PIA H W Die Geschwulste der mittleren Schadelgrube in Arteriogramm Zbl Neurochir 12 (1952) 145

RUBERTI R Considerazioni angiografiche su un caso di tumore parasellare extradurale Riv Anat pat 10 (1955) 196

WESTBERG G Angiographic changes in neurinoma of the trigeminal nerve Acta radiol 1 D (1963) 513

FROM REP. RADIOLOGICO, OSPEDALE S. CAMILLO, ROME, ITALY

ANATOMIC-RADIOLOGIC STUDY OF THE SMALL SUPERFICIAL VESSELS OF THE BRAIN

by

SANDRO SASSAROLI, TOMMASO DI GIULIO and ANTONIO BACIOCCO

Between the emptying of the arteries and before definite filling of the major veins small vessels roughly parallel and resembling railroad tracks (Fig. 1) are visible on serial angiograms. They are situated on the brain surface and in a lateral film they form a compound ribbon like image whose bends closely follow the brain sulci and border the convolutions.

The deep vessels belonging to the white matter are branches of the surface network, entering the various layers of the cortex as short, middle or long pre-capillary vessels. Most of the small arterial branches are arranged in convergent fashion and pass the white matter in the direction of the lateral ventricles. The deepest vessels are the perforating basal arteries, which in general appear to branch concentrically around the basal nuclei. This pattern of distribution is the same in all parts of the brain (KAPLAN 1956). During the angiographic intermediate phase the vessels of the white matter are not individually recognizable on the film. They only contribute to the diffusely increased density of the brain which is normal in this phase. The ventricles may stand out as a faint negative image against the brain substance (Fig. 2).

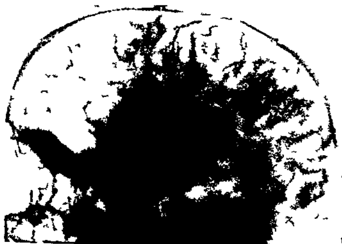


Fig 1 The small ess ls in the precapillary phase g e an impression of the anatomy of the sulci and convolutions



F g 2 Faint neg ti e m ge of the late al ventricle dur ng ng og aphy

A number of the smallest vessels branching on the cortex cross the convolu ions at random while others especially little veins emerging from the convolu ions lie in the sulci In a lateral film the vessels of the convexity and of the medi l flat surface of the hemisphere overlap The average diameter of vessels

FROM REP. RADIOLOGICO, OSPEDALE S. CAMILLO, ROME, ITALY

ANATOMIC-RADIOLOGIC STUDY OF THE SMALL SUPERFICIAL VESSELS OF THE BRAIN

by

SANDRO SASSAROLI, TOMMASO DI GIULIO and ANTONIO BACIOCCO

Between the emptying of the arteries and before definite filling of the major veins, small vessels roughly parallel and resembling railroad tracks (Fig. 1) are visible on serial angiograms. They are situated on the brain surface and in a lateral film they form a compound ribbon like image whose bends closely follow the brain sulci and border the convolutions.

The deep vessels belonging to the white matter are branches of the surface network, entering the various layers of the cortex as short, middle or long precapillary vessels. Most of the small arterial branches are arranged in convergent fashion and pass the white matter in the direction of the lateral ventricles. The deepest vessels are the *perforating* basal arteries, which in general appear to branch concentrically around the basal nuclei. This pattern of distribution is the same in all parts of the brain (KAPLAN 1956). During the angiographic intermediate phase the vessels of the white matter are not individually recognizable on the film. They only contribute to the diffusely increased density of the brain which is normal in this phase. The ventricles may stand out as a faint negative image against the brain substance (Fig. 2).



Fig 4



Fig 5



Fig 6

Fig 4 Transverse section of an injected specimen

Fig 5 Frontal pole hollowed out by removal of white matter showing the pattern of the superficial vessels Contrast material has leaked into the sulci from ruptured vessels in the sulci

Fig 6 The same appearance in another case before the brain was removed from the skull

the smaller the vessels concerned in a displacement the more significant is the finding for localization purposes In fact in the case of tumors the displacement of large arteries or veins is a compromise between the focal pressure and the brain changes due to herniations This is particularly true of avascular superficial tumors or with a growth which impinges on the cortex (Figs 7 8 and 9)

Our observations led to the following conclusions

1 A number of fine superficial vessels particularly small veins are crowded into the sulci and consequently allow the observer to gain a general idea of the shape of the cortex at angiography



Fig 3 Coronal section through body of lateral ventricles and basal ganglia The brain was previously injected through the internal carotid The superficial vessels are clearly recognizable a number are running in the sulci Some of the smallest arteries cross at random through the convolutions Concentric arrangement of white matter vessels which are so small that they are not recognizable as single vessels in an angiogram of the living

occupying the sulci ranges from 300 to 500 microns, their thickness is difficult to evaluate on the films because some of them lie close together and may overlap, causing a compound image (Fig 1) The short vessels branching within the cortex may also overlap, thus contributing to the formation of the convolutional angiographic pattern

In order to study the degree to which the contrast filled vessels of the cortex and of the white matter contribute to the angiographic image during the pre capillary phase, we made an anatomical investigation We injected 15 human brains with variable amounts of vermilion suspension in a colloidal solution Films were made of these brains or of their sections immediately after the injection or after fixation (Figs 3 and 4) We succeeded in obtaining films similar to those reported by LAZORTHES (1961) and to one reported by SCHOENMACKERS & VIETEN (cf their Fig 46) In some cases the images were particularly interesting because there was leakage of the contrast medium into the sulci caused by rupture of some of the smallest vessels (Figs 5 and 6) We found that these small superficial vessels are particularly valuable in giving an idea of the general shape of the cortex Sometimes we may gain more information from the behavior of these vessels than from larger ones and we feel that as a rule



Fig 4



Fig 5



Fig 6

Fig 4 Transverse section of an injected specimen

Fig 5 Frontal pole hollowed out by removal of white matter showing the pattern of the superficial vessels Contrast material has leaked into the sulci from ruptured vessels in the sulci

Fig 6 The same appearance in another case before the brain was removed from the skull

the smaller the vessels concerned in a displacement the more significant is the finding for localization purposes In fact in the case of tumors the displacement of large arteries or veins is a compromise between the focal pressure and the brain changes due to herniations This is particularly true of avascular superficial tumors or with a growth which impinges on the cortex (Figs 7 8 and 9)

Our observations led to the following conclusions

1 A number of fine superficial vessels, particularly small veins are crowded into the sulci and consequently allow the observer to gain a general idea of the shape of the cortex at angiography



Fig 3 Coronal section through body of lateral ventricles and basal ganglia The brain was previously injected through the internal carotid The superficial vessels are clearly recognizable a number are running in the sulci Some of the smallest arteries cross at random through the convolutions Concentric arrangement of white matter vessel which are so small that they are not recognizable as single vessels in an angiogram of the living

occupying the sulci ranges from 300 to 500 microns, their thickness is difficult to evaluate on the films because some of them lie close together and may overlap, causing a compound image (Fig 1) The short vessels branching within the cortex may also overlap, thus contributing to the formation of the convolutional angiographic pattern

In order to study the degree to which the contrast filled vessels of the cortex and of the white matter contribute to the angiographic image during the pre capillary phase, we made an anatomical investigation We injected 15 human brains with variable amounts of vermilion suspension in a colloidal solution Films were made of these brains or of their sections immediately after the injection or after fixation (Figs 3 and 4) We succeeded in obtaining films similar to those reported by LAZORTHES (1961) and to one reported by SCHOENMACKERS & VIETEN (cf their Fig 46) In some cases the images were particularly interesting because there was leakage of the contrast medium into the sulci caused by rupture of some of the smallest vessels (Figs 5 and 6) We found that these small superficial vessels are particularly valuable in giving an idea of the general shape of the cortex Sometimes we may gain more information from the behavior of these vessels than from larger ones and we feel that as a rule

SUMMARY

Anatomic and radiologic investigations show the possibility of recognizing the convolutions and sulci of the brain in the intermediate phase of carotid angiography. The visible vessels of the cortex during this phase are often particularly useful in the demonstration of expansive lesions.

ZUSAMMENFASSUNG

Anatomische und radiologische Untersuchungen geben die Möglichkeit die Windungen und Furchen des Gehirns in der intermediären Phase einer Carotisangiographie zu erkennen. Die in dieser Phase an der Hirnoberfläche sichtbaren Gefässe sind für die Diagnose von expansiven Processen oft sehr wichtig.

RESUME

Des recherches anatomiques et radiologiques ont démontré la possibilité de reconnaitre les circonvolutions et les sillons du cerveau à la phase intermédiaire de l angiographie carotidienne. Les vaisseaux corticaux visibles à cette phase sont souvent particulièrement utiles pour le diagnostic de lesions expansives.

REFERENCES

KAPLAN H A. Arteries of the brain. An anatomic study. Acta radiol 46 (1956) 364.

LAZHORTES G. Vascularisation et circulation cerebrales. Masson Paris 1961.

SCHOENMACKERS J. und VIETEN H. Atlas postmortalen Angiogramme. Thieme Verlag, Stuttgart 1954.

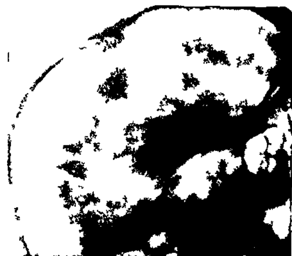


Fig 7 Appearance of the sulci and convolutions in a frontal tumor



Fig 8 Sulci and convolutions in a frontoparietal tumor

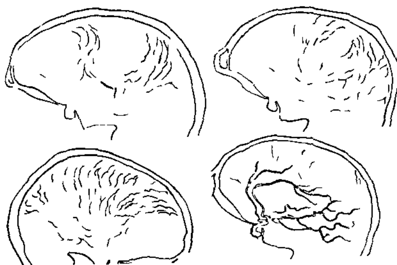


Fig 9 Diagrammatic representation of the displacement of the superficial vessels in different tumor localizations

2 Changes of the width of the sulci or the convolutions (narrowness or enlargement) are the result of pressure or an infiltrating lesion but may sometimes also be found in atrophic conditions

3 The circular arrangement of the sulci surrounding an avascular area is a common localizing sign

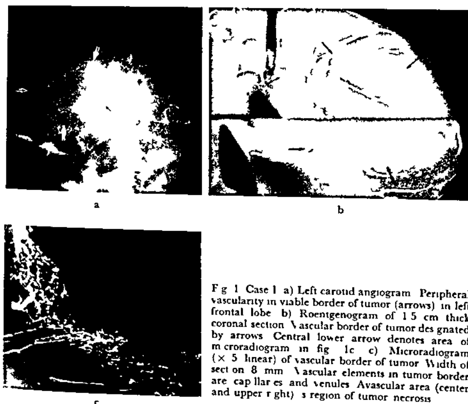


Fig 1 Case 1 a) Left carotid angiogram Peripheral vascularity in viable border of tumor (arrows) in left frontal lobe b) Roentgenogram of 1 5 cm thick coronal section Vascular border of tumor designated by arrows Central lower arrow denotes area of microradiogram in fig 1c c) Microradiogram (× 5 linear) of vascular border of tumor Width of section 8 mm Vascular elements in tumor border are capillaries and venules Avascular area (center and upper right) is region of tumor necrosis

Technique

The brain is injected immediately after removal from the cranium Both hemispheres are injected via the internal carotid and basilar arteries Open or torn arteries of significant size are ligated prior to injection The contrast agent (one part Thorotrast two parts Micropaque and three to four parts water) is injected slowly by hand Satisfactory internal brain filling is usually present when fine surface arteries are outlined with contrast material and this is obtained with approximately 30 to 50 ml of contrast agent per hemisphere

The brain is allowed to fix in the usual fashion (two to three weeks 20 % formol saline) Roentgenograms of the gross brain after sagittal sectioning are then made These are followed by roentgenograms of the appropriate coronal sections Photographs of these coronal sections are also made for subsequent correlation

Using the coronal section films as a guide microradiography of thick (to 1 cm) and thin (to 3 mm) tumor slices are made The microradiographic unit

FROM THE DEPARTMENT OF RADIOLOGY, SCHOOL OF MEDICINE, YALE UNIVERSITY AND THE RADIOLOGIC SERVICE, GRACE NEW HAVEN COMMUNITY HOSPITAL, AND DEPARTMENT OF RADIOLOGY, ST GEORGES HOSPITAL, LONDON (ATKINSON MORLEY'S UNIT), ENGLAND

POST MORTEM BRAIN TUMOR ANGIOGRAPHY

by

JAMES H SCATLIFF, M R CROMPTON and J W D BULL

Although considerable knowledge now exists concerning the in vivo angiographic appearance of brain neoplasms little or no radiographic evaluation of tumor vessels in these lesions has been carried out at post mortem The reasons for this have included unsatisfactory filling of tumor vessels by available contrast agents, surgical alteration of tumors, and limitations in supply of tumor material at any one institution

In 1961, CHANG & TREMBLEY (2) using a combination of Thorotrast and finely ground barium sulphate (Micropaque) produced excellent filling of renal and cerebral capillaries in several animal species This mixture of contrast materials has now been used to initiate a survey of the angio architecture of primary brain tumors and cerebral metastases The material for this study has been derived from a series of fifty brain injections carried out at two institutions (St Georges Hospital London (Atkinson Morley s Unit) and Yale University Medical Center) over an eighteen month period

The purpose of this report is to describe the injection and radiographic technique employed and present several cases which illustrate the method Preliminary observations will also be made concerning the tumor vasculature which has been analyzed

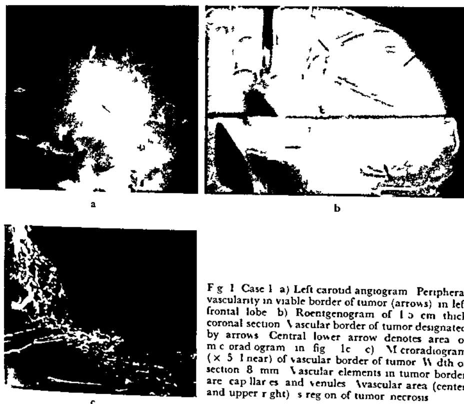


Fig 1 Case 1 a) Left carotid angiogram Peripheral vascularity in viable border of tumor (arrows) in left frontal lobe b) Roentgenogram of 1 5 cm thick coronal section Vascular border of tumor designated by arrows Central lower arrow denotes area of microradiogram in fig 1c c) Microradiogram (× 5 linear) of vascular border of tumor Width of section 8 mm Vascular elements in tumor border are capillaries and venules Avascular area (center and upper right) is region of tumor necrosis

Technique

The brain is injected immediately after removal from the cranium Both hemispheres are injected via the internal carotid and basilar arteries Open or torn arteries of significant size are ligated prior to injection The contrast agent (one part Thorotrast two parts Micropaque and three to four parts water) is injected slowly by hand Satisfactory internal brain filling is usually present when fine surface arteries are outlined with contrast material and this is obtained with approximately 30 to 50 ml of contrast agent per hemisphere

The brain is allowed to fix in the usual fashion (two to three weeks 20 % formol saline) Roentgenograms of the gross brain after sagittal sectioning are then made These are followed by roentgenograms of the appropriate coronal sections Photographs of these coronal sections are also made for subsequent correlation

Using the coronal section films as a guide microradiography of thick (to 1 cm) and thin (to 3 mm) tumor slices are made The microradiographic unit

FROM THE DEPARTMENT OF RADIOLOGY, SCHOOL OF MEDICINE, YALE UNIVERSITY AND THE RADIOLOGIC SERVICE, GRACE NEW HAVEN COMMUNITY HOSPITAL, AND DEPARTMENT OF RADIOLOGY, ST GEORGES HOSPITAL, LONDON (ATKINSON MORLEY'S UNIT), ENGLAND

POST MORTEM BRAIN TUMOR ANGIOGRAPHY

by

JAMES H SCATLIFF, M R CROMPTON and J W D BULL

*Although considerable knowledge now exists concerning the in vivo angio*graphic appearance of brain neoplasms little or no radiographic evaluation of tumor vessels in these lesions has been carried out at post mortem The reasons for this have included unsatisfactory filling of tumor vessels by available contrast agents, surgical alteration of tumors, and limitations in supply *of tumor material at any one institution*

In 1961, CHANG & TREMBLEY (2) using a combination of Thorotrast and finely ground barium sulphate (Micropaque) produced excellent filling of renal and cerebral capillaries in several animal species This mixture of contrast materials has now been used to initiate a survey of the angio architecture of primary brain tumors and cerebral metastases The material for *this study* has been derived from a series of fifty brain injections carried out at two institutions (St Georges Hospital London (Atkinson Morley s Unit) and Yale University Medical Center) over an eighteen month period

The purpose of this report is to describe the injection and radiographic technique employed and present several cases which illustrate the *method* Preliminary observations will also be made concerning the tumor vasculature which has been analyzed

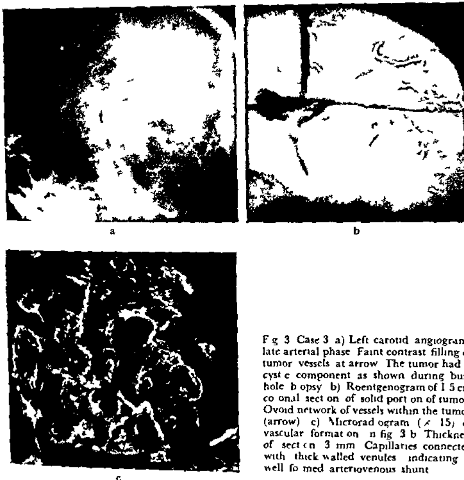


Fig 3 Case 3 a) Left carotid angiogram late arterial phase Faint contrast filling of tumor vessels at arrow The tumor had a cystic component as shown during burr hole biopsy b) Roentgenogram of 1 5 cm coronal section of solid portion of tumor Ovoid network of vessels within the tumor (arrow) c) Microradiogram (× 15) of vascular formation in fig 3 b Thickness of section 3 mm Capillaries connected with thick walled venules indicating a well formed arteriovenous shunt

Illustrative cases

Case 1 The patient was a 60 year-old female with progressive right hemiparesis and severe impairment of speech Left carotid angiography revealed a ring like tumor stain in the left frontal lobe (Fig 1 a) The patient expired one day after burr hole biopsy A roentgenogram of a coronal section 1 5 cm thick (Fig 1 b) showed the tumor vessels to be well filled with contrast material A microradiogram of an 8 mm thick section of the lesion (Fig 1 c) outlined a band of capillaries and venules of irregular configuration in the viable tumor border The histology of the tumor was astrocytoma grad III (e)

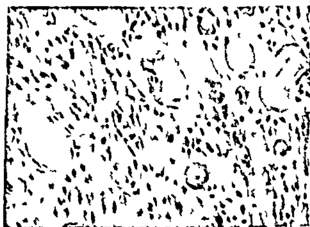
Case 2 This 47 year-old male had a three month history of lethargy and personality disturbance A slowly developing right hemiparesis was also noted Left carotid angiography produced a rounded well defined tumor stain in the region of the left basal ganglia and thal



a



b



c

Fig 2 Case 2 Roentgenogram of coronal section (1.5 cm) shows well vascularized astrocytoma in thalamus and basal ganglia (arrows) Dilatation of lenticulostriate arteries supplying tumor Upper arrow denotes area of contrast material extravasation in tumor *b)* Microradiogram (× 2) of 8 mm thick section of tumor taken from coronal slice shown in fig 2 a Abrupt ending of capillaries in areas of central necrosis (avascular regions in center and lower left of tumor) c) Histologic section (× 100) Capillaries from 10—25 micra in tumor well filled with contrast material

used for the majority of the specimens contains a Machlett type O 2 defraction tube with a 1 mm focal spot 3 1/4 × 4 Kodak projector slide plates have proved satisfactory for filming Histologic sections (7 micra) are then made from the same slices for tumor classification and evaluation of vessel types and degree of vessel filling

The microradiograms are then viewed microscopically or may be examined after photographic enlargement The films of the microradiograms for this report were made by *first producing an intermediate negative (Cronar film* Dupont) with a photographic enlarger The intermediate film was then copied with a Log Etronic printer In this way the microradiographic image can be enhanced as well as enlarged 10 to 20 times with satisfactory preservation of detail

in the red blood cells and benzidinenitroprusside, Pickworth stain (11) or acid fuchsin EROS (4) will produce a deposition of dark pigment in the vessel lumina The demonstration of tumor capillaries is dependent on a blood filled vascular bed prior to the application of the dye Agonal changes in the vessels as well as handling and sectioning of tissues may disperse erythrocytes to such an extent that only a partial outline of tumor vessels is obtained In addition tissue sections used in staining procedures are generally 150 to 300 micra thick and the resulting patterns seen have a scattered or fragmented appearance

A second histologic approach of greater merit is the use of silver stains as recommended by COURVILLE (3) Silver impregnation of the reticulin in the vessel wall would appear to give a more thorough outline of vessels at a capillary level and the illustrations of the results of this method are quite striking The width of the sections of approximately 250 micra poses a limitation however similar to that found in erythrocyte staining methods It is evident that vascular formations (see Fig 3 c) with dimensions greater than 250 micra may be transected in thin sections and go unrecognized

Another technique advocated for the study of cerebral vessels has been the use of plastic injection casts NYSTROM (9) has employed this method in the delineation of the vasculature of gliomas as well as cerebral metastases A distinct advantage of this technique is the outlining of arteries and veins with plastics of different colors thereby producing easy identification of the vascular components in the tumor mass Unfortunately inspection of the photographs of the casts made by NYSTROM would seem to indicate that only large tumor vessels are filled and that a major part of the capillary circulation is not outlined Also the digestion of surrounding cerebral tissue is time consuming and the relationship of the pathologic vessels to the tumor is lost

The value of contrast material injection and radiographic study of pathologic intracerebral vessels has been highlighted by RUSSELL (12) in his study of small aneurysms (300 to 900 micra) arising from the lenticulostriate arteries in middle aged hypertensive and normotensive patients Using a combination of micropaque gelatin and water RUSSELL was able to fill arterioles down to 30 micra and occasionally venous structures were visible following the passage of contrast material through the normal capillary bed

Although the very fine particulate size of the contrast material (Thorotrast 0 1 micra and Micropaque 0 1—3 0 micra) employed in the present study is helpful in filling tumor vessels down to 10 to 25 micra there are other important factors that contribute to the success of the method In many of the injections there appeared to be a preferential filling of tumor vessels by the contrast agent It must be assumed and as pointed out by HARDMAN (6), that

amus Because of the sharp delineation and almost homogeneous appearance a large metastasis was favored prior to death A diffuse irregular meshwork of capillaries was found throughout the tumor (Fig 2a) with accompanying spotty areas of central necrosis Dilatation of the lenticulostriate arteries supplying the tumor as well as the irregular distribution of necrotic areas in the tumor was well shown in a microradiogram (Fig 2b) of an 8 mm thick section taken from the coronal section shown in Fig 2a A 10 micra histological section (Fig 2 c) from the same tumor area showed that capillaries down to 10—15 micra were filled with contrast agent without evidence of extravasation The microscopic diagnosis of the tumor was astrocytoma grade IV

Case 3 This 48 year old woman had become disoriented over an eight week period On admission a moderate right hemiparesis and right facial weakness was found Left carotid angiography revealed elevation and stretching of vessels of the middle cerebral group and a faint small contrast material stain was seen in the late arterial phase (Fig 3 a) The radiologic diagnosis was a probable astrocytoma with cyst formation although a small angioma with an associated intracerebral hematoma could not be excluded A cyst was tapped containing xanthochromic fluid At post mortem only the left cerebral hemisphere was injected and a roentgenogram of the coronal section bearing a solid part of the tumor showed the tumor vessels to be well filled (Fig 3 b) In several areas the vessels appeared to be arranged in rounded clusters Microradiography of one of these formations (Fig 3 c) measuring approximately 3 × 6 mm showed an intricate network of vessels interspersed between viable and necrotic tumor Histologic sections showed astrocytoma grade III The vascular elements in the formation shown consisted of arterioles dilated capillaries and venules with thickened muscular walls indicating a well formed arteriovenous shunt

Case 4 This 42 year old male had severe frontal headaches for three weeks prior to admission EEG suggested a right frontotemporal lesion and a right carotid angiography showed extensive pathologic vascularity in the right frontal lobe consistent with an advanced glioblastoma At surgery only partial removal of the right frontal lesion could be carried out Coronal section roentgenograms showed marked tumor vascularity remaining in the right frontal lobe Extension of tumor with its associated vascular supply to the opposite hemisphere via the corpus collosum had occurred A microradiogram (Fig 4) showed prominent arteriovenous connections of the tumor mass in the corpus callosum and septum pellucidum Histologic sections revealed astrocytoma grade IV

Case 5 This 54 year old male exhibited signs of progressive confusion over a three week period A chest film showed a mass in the left hilum Bilateral carotid angiography was negative At post mortem multiple cerebral metastases were found which had originated from a lung carcinoma The largest deposit noted which was a little over 1 cm in diameter was well filled with the contrast agent as shown in coronal section radiography (Fig 5a) A microradiogram (Fig 5b) of a 3 mm thick section through this lesion revealed a conglomeration of tumor vessels with an area of central necrosis and some extravasation of contrast material

Discussion

During the last thirty five years several techniques have been developed for the post mortem evaluation of pathologic vessels in the brain The foremost of these has been the use of erythrocyte stains The interaction of hemoglobin



a

Fig 5 Case 5 a) Roentgenogram of 1 5 cm coronal sect on bearing well vasculari ed metastasis (arrow) f om l ng carcinoma b) Microrad ogram (× 7) of metasta is in fig 5 Section 3 mm th ck closely packed capill r es around area of central necros s Extra va t on of contra t in area hemorrhage in tumor



b

generated by low voltage (10—20 kV) microradiographic units, as well as the use of fine grain photographic emulsions are primarily responsible for the good resolution of small vessels This is well shown by examination of Fig 1 b and c The coronal section radiogram in Fig 1 b was produced by standard roentgen film at 50 kV and 10 mAs Although the tissue thickness of this specimen is approximately twice that of the microradiographic section (Fig 1 c) the resolution of vascular detail in the region of the arrow (Fig 1 b) is considerably less when the two films (without magnification) are compared It is also of interest that photographic enlargement of specimens roentgen examined with industrial film as suggested by McAlister (8) does not appear to give the same vascular detail as obtained with microradiography

The time required to produce microradiograms is surprisingly short With the unit described an exposure of approximately 1 minute per millimeter of tissue thickness is required at 20 kV and 10 mA Photographic enlargement of the microradiogram is carried out easily and vascular detail can be further improved when television amplification (LogEtronic) methods are used

Hardman (6) in his description of the angioarchitecture of gliomas with a high grade of malignancy suggested that each had a large area of central ne crosis surrounded by a narrow rind of tumor containing capillaries and sinus oids He distinguished four vascular zones around and in the lesion The outer zone (Zone A) in the surrounding white matter exhibited either a nor mal capillary network or arterioles and capillaries compressed by adjacent

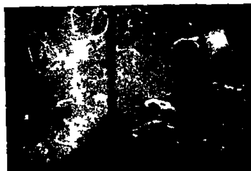


Fig 4 Case 4 Microradiogram (× 2) of tumor vascularity of *transfrontal astrocytoma* *Thickness of section 6 mm* *Tributaries* from pericallosal artery as well as dilated capillaries of tumor in corpus callosum and septum pellucidum are seen Contrast material also fills the septal veins

dilated vessels supplying the tumor as well as arteriovenous connections, particularly within the glioblastomas, provide areas of decreased vascular resistance and this permits more thorough filling of tumor vessels with contrast agent It is estimated that some of the injections outlined as much as 75 % of the vascular bed including tumor capillaries, although in general the success rate ranges between 40—50 %

Another factor which expedites vessel filling is the nearly intact state of the tumor vessels at the time of autopsy The majority of brains injected had either no previous surgical transformation or were subjected to diagnostic biopsy only In the biopsied brains, although bleeding did occur at the biopsy site, it was found at post mortem that the central, and usually necrotic portion of *the tumor, was hemorrhagic and a considerable portion of the* vasculature in the peripheral viable areas of the tumor was not distorted Of interest is the fact that surprisingly little extravasation of contrast material occurred in the tumors This can probably be accounted for again on the basis of decreased vascular resistance in the tumor and the intact state of the tumor vessels at autopsy

Microradiography aids considerably in the assessment of the angioarchitecture of normal and pathologic tissue The clarity of injected vessels, particularly at a capillary level, has been well shown by several authors including BARCLAY (1), CHANG (2) and PEREZ (10) The longer x ray wave lengths



a



b

Fig 5 Case 5 a) Roentgenogram of 1 5 cm coronal section bearing well vascularized metastasis (arrow) from lung carcinoma b) Microradiogram (× 7) of metastasis in fig 5 a Section 3 mm thick closely packed capillaries around area of central necrosis Extravasation of contrast in area hemorrhage in tumor

generated by low voltage (10—20 kV) microradiographic units as well as the use of fine grain photographic emulsions are primarily responsible for the good resolution of small vessels This is well shown by examination of Fig 1 b and c The coronal section radiogram in Fig 1 b was produced by standard roentgen film at 50 kV and 10 mAs Although the tissue thickness of this specimen is approximately twice that of the microradiographic section (Fig 1 c) the resolution of vascular detail in the region of the arrow (Fig 1 b) is considerably less when the two films (without magnification) are compared It is also of interest that photographic enlargement of specimens roentgen examined with industrial film as suggested by McAlister (8) does not appear to give the same vascular detail as obtained with microradiography

The time required to produce microradiograms is surprisingly short With the unit described an exposure of approximately 1 minute per millimeter of tissue thickness is required at 20 kV and 10 mA Photographic enlargement of the microradiogram is carried out easily and vascular detail can be further improved when television amplification (LogEtronic) methods are used

Hardman (6) in his description of the angioarchitecture of gliomas with a high grade of malignancy suggested that each had a large area of central necrosis surrounded by a narrow rind of tumor containing capillaries and sinusoids He distinguished four vascular zones around and in the lesion The outer zone (Zone A) in the surrounding white matter exhibited either a normal capillary network or arterioles and capillaries compressed by adjacent

tumor In some sections dilated capillaries and venules were distinguished The outer zone of vessels (Zone B) in the viable tumor border consisted of capillaries which were irregularly arranged and dilated The inner zone of vessels (Zone C) in the active portion of the tumor were interpreted as sinusoids and these were found to be generally larger than the capillaries in Zone B The necrotic center of the tumor was designated as Zone D and the vascular elements found were primarily thrombosed sinusoids

Although evaluation of the gliomata injected in the present survey is not yet complete, it would seem that HARDMAN's analysis can provide only a stereotype of the vascular anatomy of these tumors Examination of the micro radiograms of the tumors in the first three patients (Figs 1 c, 2 b and 3 c) indicates that considerable variation in vascular formation is present

In Case 1 (Fig 1 c) the vascular border of the tumor is well defined between the central area of necrosis and normal brain A variation in caliber of vessels is present throughout the viable tumor border and division of vessels into zones, i e, peripheral small capillaries and inner dilated sinusoids is not possible In this case, although widened tortuous channels (sinusoids) could be seen in several sites along the necrotic margin of the tumor, for the most part, thrombosed capillaries which have not undergone dilatation end abruptly in the necrotic portion of the lesion The abrupt ending of capillaries without deformation by the necrotic portion of the tumor is well shown in Case 2 (Fig 2 b), and this configuration has been noted in the majority of the gliomas examined at present Possibly, a rapid rate of tumor growth in the more malignant lesions does not permit the development of drainage channels on the inner aspect of the viable tumor border In all probability, the capillary bed in this area is engulfed rapidly by the necrotic debris of the tumor In Case 3 (Fig 3 c), on the other hand, well preserved networks of vessels were noted throughout the tumor mass Histologic sections showed well developed arterio venous shunts with evidence of muscular hypertrophy along the walls of draining venules indicating the presence of increased blood flow

It is interesting to note that Cases 1 and 3 were both graded as astrocytoma grade III and yet a markedly different angio architecture is present in the lesions In Case 1 the vascular structures appear to support the growth of the viable edge of the tumor without an organized pattern There is no specific vascular arrangement other than a circumferential one and this appears to be dictated by the expanding necrotic center of the tumor

In Case 3, although a large center of liquefactive necrosis was present, well developed and repetitive constellations of vessels were seen The reasons for this disparity are not yet apparent in our studies Possibly, although the lesions have the same grade of malignancy Case 3 was a more slowly growing tumor

and more time was available for the tumor mass to prepare a well organized vascular bed Perhaps a greater understanding of this problem can be gained by the study of the angio architecture of gliomas transplanted to laboratory animals GREENE (5) has shown that human brain tumors can be transplanted to guinea pig and mouse brains with subsequent varying rates of tumor growth Injection studies in these animals and histological correlation may give some insight concerning the development of tumor angioarchitecture in relation to tumor growth as well as vascular formations in varying types and grades of malignancy

Some preliminary observations may be made regarding the correlation of cerebral angiographic tumor stains and the same tumor angioarchitecture outlined by injection at post mortem It would appear that when prominent central necrosis is present in a glioma a critical thickness of tumor capillaries and sinusoids must be present before a recognizable angiographic stain is seen In several cases studied although an obvious displacement of major or secondary vessels was present no tumor stain could be seen The post mortem injection roentgenograms and histologic confirmation revealed a fringe of contrast material filled vessels usually less than 1/2 cm wide

It is also of interest to note that in two brains examined with multiple metastases from carcinoma of the lung bilateral cerebral angiographies were carried out and no contrast filling of tumor vessels could be seen The metastases were generally 1 cm or less in diameter and the majority of these were well filled with contrast material (see Fig 5 b) during post mortem injection Although it is well known that metastatic lesions may not be seen during cerebral angiography the findings in this study underline the fact that the size of the lesion is important in determining the presence of an in vivo angiographic stain

Acknowledgements

The authors wish to thank Mr Wylie Mc Kissock for his permission to initiate and carry this project forward at the Atkinson Morley s Unit St George s Hospital London Thanks are also extended to Doctor G B Solitare of the Department of Neuropathology at the Yale Med cal Center and Dr G I DeSuto-Nagy of the Department of Pathology at the West Haven Connecticut Veterans Hospital for their help in the analysis of the pathologic material The study wa supported by Grant (BT 1050) U S Public Health Service

SUMMARY

A post mortem brain tumo injection techniqu employing a mixture of Thorotrast and Micropaque is described by which 50 to 75 % of the tumor circulation at a capillary level can be outl ned Considerable variation was noted in the size number and configuration

of vascular elements throughout the viable sections of gliomas In order to obtain in vivo angiographic identification of a glioma with prominent central necrosis it would appear that the tumor must have a vascular border 1/2 cm or greater in thickness Well vascularized metastases under 1 cm in diameter could not be demonstrated during cerebral angiography

ZUSAMMENFASSUNG

Es wird die Technik einer Injektion eines Hirntumors post mortem mit einer Mischung von Thorotrast und Micropaque womit 50—75 % der Tumorgefässe dargestellt werden konnen beschrieben Die Gefässelemente in den viablen Teilen von Gliomen variierten bedeutend in ihrer Grösse Anzahl und Form Um eine angiographische Darstellung eines Glioms mit bedeutender zentraler Nekrose in vivo zu erhalten muss der Tumor allem Anschein nach ein Mindestmass von 1/2 cm Dicke haben Gut vaskularisierte Metastasen unter 1 cm Durchmesser konnten mittels cerebraler Angiographie nicht zur Darstellung gebracht werden

RÉSUMÉ

Description d une technique d injection post mortem des tumeurs cérébrales par un mélange de Thorotrast et de Micropaque qui permet de remplir 50 a 75 % de la circulation tumorale à l étage capillaire Les auteurs ont constaté des variations considérables dans le calibre le nombre et la configuration des éléments vasculaires dans les parties viables des gliomes Pour qu on puisse identifier in vivo par angiographie un gliome présentant une *importante nécrose centrale il semble qu il faut* que la tumeur ait une coque vascularisée ayant au moins un demi centimètre d épaisseur Il n a pas été possible de mettre en évidence par angiographie cérébrale des métastases bien vascularisées de moins d un centimètre de diamètre

REFERENCES

1 BARCLAY A F and BENTLEY F H The vascularization of the human stomach A preliminary note on the shunting of trauma Brit J Radiol 32 (1949) 62

2 CHANG C H and TREMBLEY B Microangiographic studies of kidney and brain in animals Technical aspects Yale J Biol Med 33 (1961) 451

3 COURVILLE C B Vascular pattern of the encephalic gray matter in man Bull Los Angeles neurol Soc 23 (1958) 30

4 EROS G Method for fuchsin staining of the network of cerebral blood vessels Arch Path 31 (1941) 215

5 GREENE H S N The transplantation of human brain tumors to the brains of laboratory animals Cancer Res 13 (1953) 422

6 HARDMAN J The angio architecture of the gliomata Brain 63 (1940) 91

7 KERNOHAN J W MAHON R F SVIEN H J and ADSON A W A simplified classification of the gliomas Proc Mayo Clin 24 (1949) 71

8 MCALISTER W H MARGULIS A R HEINBECKER P and SPJUT H Arteriography and microangiography of gastric and colonic lesions Radiology 79 (1962) 769

9 NYSTROM S Pathological changes in blood vessels of human glioblastoma multiforme Acta path microbiol scand (1960) Suppl No 137
10 PEREZ C A HODGES F J and MARGULIS A R Microradiography in experimental cerebral edema in rats Radiology 82 (1964) 529
11 PICKWORTH F A A new method of study of the brain capillaries and its application to the regional localization of mental disorder J Anat 69 (1934—35) 62
12 RUSSELL R W R Observations on intracerebral aneurysms Brain 86 (1963) 425

of vascular elements throughout the viable sections of gliomas In order to obtain in vivo angiographic identification of a glioma with prominent central necrosis it would appear that the tumor must have a vascular border 1/2 cm or greater in thickness Well vascularized metastases under 1 cm in diameter could not be demonstrated during cerebral angiography

ZUSAMMENFASSUNG

Es wird die Technik einer Injektion eines Hirntumors post mortem mit einer Mischung von Thorotrast und Micropaque womit 50—75 %, der Tumorgefässe dargestellt werden konnen beschrieben *Die Gefässelemente in den viablen Teilen von Gliomen variierten* bedeutend in ihrer Grosse Anzahl und Form Um eine angiographische Darstellung eines Glioms mit bedeutender zentraler Nekrose in vivo zu erhalten muss der Tumor allem Anschein nach ein Mindestmass von 1/2 cm Dicke haben Gut vaskularisierte Metastasen unter 1 cm Durchmesser konnten mittels cerebraler Angiographie nicht zur Darstellung gebracht werden

RÉSUMÉ

Description d une technique d injection post mortem des tumeurs cérébrales par un mélange de Thorotrast et de Micropaque qui permet de remplir 50 à 75 % de la circulation tumorale a l étage capillaire Les auteurs ont constaté des variations considérables dans le calibre le nombre et la configuration des éléments vasculaires dans les parties viables des gliomes Pour qu on puisse identifier in vivo par angiographie un gliome présentant une importante nécrose centrale il semble qu il faut que la tumeur ait une coque vascularisée ayant au moins un demi centimètre d épaisseur Il n a pas été possible de mettre en évidence par angiographie cérébrale des métastases bien vascularisées de moins d un centimètre de diamètre

REFERENCES

1 BARCLAY A E and BENTLEY F H The vascularization of the human stomach A preliminary note on the shunting of trauma Brit J Radiol 32 (1949) 62

2 CHANG C H and TRIMBLEY B Microangiographic studies of kidney and brain in animals Technical aspects Yale J Biol Med 33 (1961) 451

3 COURVILLE C B Vascular pattern of the encephalic gray matter in man Bull Los Angeles neurol Soc 23 (1958) 30

4 FROS G Method for fuchsin staining of the network of cerebral blood vessels Arch Path 31 (1941) 215

5 GREENE H S N The transplantation of human brain tumors to the brains of laboratory animals Cancer Res 13 (1953) 422

6 HARDMAN J The angio architecture of the gliomata Brain 63 (1940) 91

7 KERNOHAN J W MAHON R F SVIEN H J and ADSON A W A simplified classification of the gliomas Proc Mayo Clin 24 (1949) 71

8 MCALISTER W H MARGULIS A R HEINBECKER P and SPJUT H Arteriography and microangiography of gastric and colonic lesions Radiology 79 (1962) 769

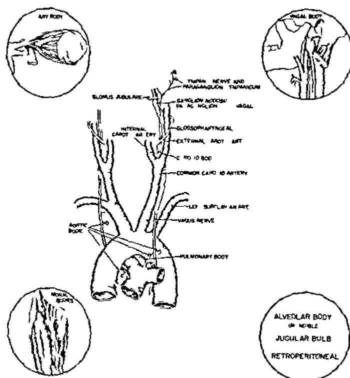


Fig 1 Sites of chemoreceptor tissue (after LECOMPTE)

ogy and behavior of this tumor and have led to a multitude of terminologies The term carotid body tumor familiar to all is slowly losing favor to the more appropriate chemodectoma (MULLIGAN 1950) which is receiving increased recognition (Editorial J Amer med Ass 1964) The carotid body was discovered by VON HALLER in 1743 and in 1891 MARCHAND first described a case of a carotid body tumor RIEGNER removed the first carotid chemodectoma in 1880 (BYRNE 1958)

There are a number of histologically similar structures located in various parts of the body and aggregates of such tissue have been described at other sites in addition to the carotid bifurcation and the jugular foramen Since the chemoreceptor tissue at these various sites has been assumed to be similar a classification may be based on anatomic location (BOYD 1937 see Fig 1)

Rare tumors arise from the vagal body (BURMAN 1955 and 1956) aortic body (LATTES 1950 DUNCAN & MCDONALD 1951 MACDONALD 1956) ciliary body (FISHER & HAZARD 1952 LATTES MCDONALD & SPROUL 1954) mandible (BURMAN 1956) femoral body (SMETANA & SCOTT 1951

FROM THE NEURORADIOLOGICAL UNIT (CHIEF M M SCHECHTER) OF THE DEPARTMENT OF RADIOLOGY (DIRECTOR F RUZICKA) AND THE NEUROLOGY SERVICE (CHIEF J G CHUSID), ST VINCENT'S HOSPITAL AND MEDICAL CENTER OF NEW YORK, AND FROM THE DIVISION OF NEURORADIOLOGY (CHIEF M M SCHECHTER) OF THE DEPARTMENT OF RADIOLOGY (DIRECTOR M ELKIN), ALBERT EINSTEIN COLLEGE OF MEDICINE, NEW YORK, U S A

CHEMODECTOMAS OF THE CAROTID BIFURCATION

by

MANNIE M SCHECHTER and JOSEPH G CHUSID

The two carotid bodies are highly vascularized chemoreceptor organs located at the carotid bifurcations and important in the reflex control of respiration Each carotid body (glomus caroticum) contains islands of chemoreceptor cells and sustentacular cells surrounded by sinusoidal vessels (Ross 1959) Afferent nerve fibres from the carotid bodies ascend to the medulla via a branch of the glossopharyngeal nerve (nerve of Hering) Experimental studies on animals, initially undertaken by HEYMANS and coworkers *(1930) have shown* that the carotid bodies are sensitive to oxygen deficiency (decline in partial *pressure of arterial oxygen*), excess *carbon dioxide (rise in partial* pressure of arterial carbon dioxide) or increased acidity (lower arterial pH) Under these *conditions of carotid body stimulation*, the animal responds by hyperventilation with increased rate and amplitude of respiration (OBERHOLZER & TOFANI 1960, UVNAS 1960, ANICHKOV & BELENKII 1963 GANONG 1963) The functional significance of the carotid bodies in man has been assumed to be similar to that so clearly demonstrated in lower animals, but confirmation of the precise role of carotid bodies in human physiology must await further studies

Conflicting opinions appear in the literature concerning the function, histol



Fig 2 Case 5 Histologic appearance showing nests of cells (Zellballen) Hematoxylin and eosin 250

Chemodectomas are usually encapsulated globular and red brown or red gray in appearance Their consistency may vary from firm to soft and on cross section they appear homogeneous Tumor size usually ranges from 2 to 5 cm in diameter They nestle in the carotid bifurcation A plane of cleavage may be present between these tumors and the vessels or they may be intimately bound to the carotid arteries (BYRNE 1958)

Histologically nests or alveolar clusters of epithelioid cells (Zellballen) are separated by a vascular fibrous stroma LECOMPTE (1951) felt that these tumors may be divided into three groups 1) the usual or commonest type in which the normal carotid body structure is reproduced faithfully 2) the adenoma like type in which the chief cells are rounded plump with abundant cytoplasm resembling epithelium supported by scanty stroma and 3) the angioma like type in which chief cells have spindle or crescent shapes simulating endothelial cells Reticulum stains may help in demonstrating relationship between cell clusters and surrounding stroma

Variation in microscopic appearance may be noted with some areas appearing more angiomatous than others However a correlation between the histologic appearance of chemodectomas and their behaviour has not been firmly established There is no evidence that carotid chemodectomas are

RANDALL & WALTER 1954), and retroperitoneal body (SMETANA & SCOTT 1951, AREAN & DEARELLANO 1956)

Although over 500 carotid chemodectomas have been reported, many questions relating to these tumors remain unanswered and conflicting opinions appear in the literature Since the majority of these tumors are benign and slow growing with minimal associated symptoms, surgical intervention is not considered justifiable unless the tumor can be removed without sacrificing the internal carotid artery in the neck (McILRATH & REMINE 1963), or compromising its flow (CONLEY 1963) These tumors are situated in a critical anatomic site, the carotid bifurcation, and the chemodectoma often encompasses the common, internal and external carotid arteries Should the carotid artery be inadvertently interrupted in the neck, prior knowledge of the collateral supply to the brain from the opposite side would be useful

Angiography may help in establishing the diagnosis when a mass in the neck is present It is surprising to find that relatively few references have appeared in the literature on the use of angiography in the evaluation of neck tumors It is our purpose to emphasize the value of carotid angiography in the diagnosis of carotid bifurcation chemodectomas, and to report 13 cases of carotid chemodectomas

Most patients with chemodectomas of the carotid bifurcation are asymptomatic except for the presence of a painless cervical mass Growth of the tumor is usually quite slow and its discovery may be delayed until it has attained massive size In some instances, the cervical mass may be detected only as an incidental finding on routine physical examination These tumors may be present for several years and in one of our cases was known to the patient for twenty five years When the tumor becomes quite large, the patient may become aware of the mass and perhaps of some local discomfort Occasionally in masses which grow medially and project into the pharynx, dysphagia may be associated

On physical examination, the chemodectoma is usually palpable as a firm mass in the cervical region near the carotid bifurcation and usually is movable laterally but not vertically Often a slight, superficial neck swelling or bulge may be noted over the tumor area The tumor may be pulsatile and have associated bruit or thrill, making clinical distinction from aneurysm difficult Intraoral examination may disclose bulging of the oropharyngeal wall in those patients whose tumors project into this region MARTORELL (1956) claimed that pressure over the common carotid artery proximal to a carotid chemodectoma could result in diminution in the size of the tumor which would gradually assume its normal size after compression was released, aneurysms, he stated, usually assumed precompression size rapidly after release of pressure



Fig 2 Case 5 Histologic appearance showing nests of cells (Zellballen) Hematoxylin and eosin, × 250

Chemodectomas are usually encapsulated globular and red brown or red gray in appearance Their consistency may vary from firm to soft and on cross-section they appear homogeneous Tumor size usually ranges from 2 to 5 cm in diameter They nestle in the carotid bifurcation A plane of cleavage may be present between these tumors and the vessels or they may be intimately bound to the carotid arteries (BYRNE 1958)

Histologically nests or alveolar clusters of epithelioid cells (Zellballen) are separated by a vascular fibrous stroma LECOMPTE (1951) felt that these tumors may be divided into three groups 1) the usual, or commonest type in which the normal carotid body structure is reproduced faithfully 2) the adenoma like type in which the chief cells are rounded plump with abundant cytoplasm resembling epithelium supported by scanty stroma and 3) the angioma like type in which chief cells have spindle or crescent shapes simulating endothelial cells Reticulum stains may help in demonstrating relationship between cell clusters and surrounding stroma

Variation in microscopic appearance may be noted with some areas appearing more angiomatous than others However a correlation between the histologic appearance of chemodectomas and their behaviour has not been firmly established There is no evidence that carotid chemodectomas are

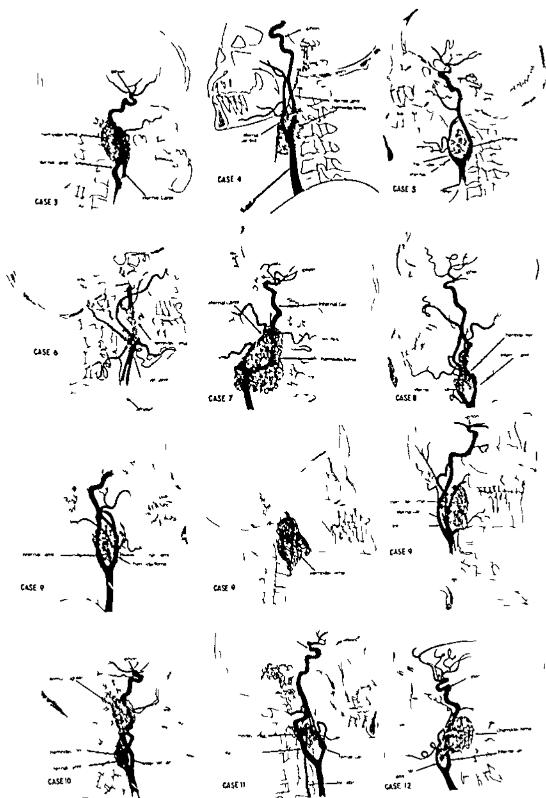


Fig. 3. For text see opposite page.

more responsive or sensitive to blood changes than normal carotid bodies Although the vast majority are clinically benign, metastases to regional lymph nodes or other distant sites have been reported This did not occur in our series

In most large series such as the Mayo Clinic s 64 cases (McILRATH & REMINE 1963) it has been noted that the majority of chemodectomas of the carotid bifurcation occur unilaterally Although these tumors are usually unilateral bilateral tumors are by no means rare (HARRINGTON CLAGETT & DOCKERTY 1941 LAHEY & WARREN 1951, BIRRELL 1952, PETTET WOOLNER & JUDD 1953 ENGSTROM & HAMBERGER 1957 BYRNE 1958, SESSIONS MCSWAIN CARLSON & SCOTT 1959 WESTBURY 1960 RUSH 1962, CONLEY 1963 MORRIS et coll 1963 REESE LUCAS & BERGMAN 1963 KROLL et coll 1964) In the series by REESE et coll (1963) four of twelve cases had bilateral tumors Two cases in our series (nos 10 and 12) had bilateral carotid chemodectomas in one the second tumor appeared after a nine year period and in the other after a ten year period One patient (Case 10) had in addition a chemodectoma of the glomus jugulare

These tumors are more common (1 7/1) in women (McILRATH & REMINE) A wide age range 6 months (WOSNESSENKI — cited by TAYLOR 1940) to 80 years (BYRNE 1958) and a long history of tumor existence 2 months to 36 years have been reported Concurrent associations i e multicentricity of carotid and glomus jugulare chemodectomas have been reported (HARRINGTON CLAGETT & DOCKERTY 1941 KIPKIE 1947 ASKENASY EPPENSTEIN & HERZBERGER 1953 SCHADE 1953 HAWKINS 1961 CONLEY 1963) This was present in Case 10 in our series

A heredo familial incidence has been claimed by LEWISON & WEINBERG (1950) LAHEY & WARREN (1951) PETTET WOOLNER & JUDD (1953) DESAI & PATEL (1961) LADENHEIM & SACHS (1961) RUSH (1962), and CONLEY (1963) CHASE (1933) reported a tumor in two sisters and LAHEY & WARREN (1947) reported tumors in three siblings of one family and two other members of the same family had excision of the tumors by other surgeons KROLL et coll (1964) report twelve individuals in two generations with carotid chemodectomas of these twelve five had tumors on both sides

The vast majority of these tumors are benign and even in malignant tumors mitotic figures are rare MIROV (1962) reported a case of a malignant carotid chemodectoma with regional invasion and metastasis A case with wide spread pulmonary metastases proven by lung biopsy was reported by FANNING WOODS & CHRISTIAN (1963) and the patient remained symptom free for over

Fig 3 Sch m t r presentat on of the chemod ctomas of the carotid b fu cation demonstrated by ang ograph n our ca es (Case 13 not included)

two years TURNBULL (1954) also reported a case with metastatic spread to lungs Bone metastases have been reported by ANDERSON & SCARCELLA (1963) DONALD & CRILE (1948) reported a case with spread to pelvis, ribs, femur and sternum GOODOF & LISCHER (1943) reported a case with spread to pancreas, and SPOTNITZ (1951) had a case with spread to cervical glands, skin, kidney, pancreas, heart and pleura Other visceral metastases reported include GRONBERGER (1917) spread to kidneys and mediastinum and GILFORD & DAVIS (1904) spread to liver Other reports of malignancy include MORFIT, SWAN & TAYLOR (1953), ROMANSKI (1954), WARREN (1959), MOBERG (1961), REESE, LUCAS & BERGMAN (1963) and MORRIS et coll (1963)

LE COMPTE (1951) stated that he had never seen a malignant carotid chemodectoma In one case in his series, a node enclosed near the tumor was involved, but this could have been due to direct extension In a case reported by RUSH (1962), local invasion was encountered in the brachial plexus REESE et coll (1963) report 13 instances of regional lymph node involvement and 15 instances of distant dissemination MACCOMB (1948) reported recurrence in nodes in the neck after resection of tumor and AREAN (1955) reported tumor extending into the spinal canal Spread to adjacent lymph glands has also been reported by SHOWAN & OWEN (1938), LAHEY & WARREN (1947), MONRO (1950), GOARMAGHTICH & PATTYN (1954), FRIEDMAN & LAU (1957), RABSON & ELLIOT (1957), and FERNAN ZEGARRA (1957)

Radiology

Apart from a soft tissue mass in the conventional film of the neck, no special changes have been reported in the literature or in our group The changes due to metastases have been excluded Negative or normal findings such as normal intervertebral foramina, and absence of bone erosion are usually observed

Carotid angiography Despite some of the unique physical findings, a correct preoperative diagnosis is often not made according to most authors LAHEY & WARREN (1951) reported 18 patients in whom a correct diagnosis was made in only 9 cases (quoting WETZEL) In the series of 5 cases reported by HAWKINS (1961) a correct diagnosis was made only after carotid angiography In WESTBURY s series (1960) in none of seven cases was a preoperative diagnosis made by the referring surgeon Bilateral angiography performed in three of the cases showed characteristic changes However, MONRO (1950) stated arteriography would appear to play no part in carotid body tumor diagnosis unless it be in the occasional case where the possibility of aneurysm can not be excluded on clinical grounds

Angiography is a most valuable diagnostic aid in the study of carotid chemodectomas (CONLEY 1963) It is usually diagnostic for the medium and the large carotid chemodectomas and is highly suggestive for the smaller ones MORRIS et coll (1963) claimed that angiography provided the most accurate diagnosis before surgery Angiography may establish a diagnosis and may also supply other information such as the size of the tumor its spatial relationship to the common internal and external carotid arteries and a collateral flow from the opposite side via the circle of Willis or extracranial anastomotic channels Lesions higher in the neck and unsuspected lesions on the opposite side may be revealed (ENGSTROM & HAMBERGER 1957)

The first angiographic study of these tumors was reported by LICHTENAUER (1938) following tumor biopsy Since then many reports have appeared (IDBOHRN 1951, WRIGHT 1952 LIPSCHITZ 1958 BORELLI 1959 MYBURGH & BERK 1959 NELSON 1962 and others)

Carotid angiography may be performed by puncturing the common carotid artery directly or introducing a catheter into this vessel from another site of puncture Selective injection into the internal and external carotid arteries may be used When a large mass is encountered the carotid artery may be punctured in a retrograde direction A dosage of 8—10 ml of contrast medium is usually sufficient Serial films should be taken to demonstrate the filling and emptying of the tumor with contrast medium Carotid angiography of the contralateral side with compression on the carotid artery of the affected side should be performed to demonstrate patency of collateral channels should it become necessary to sacrifice the involved carotid artery

The most common finding on angiography is contrast filling of the vascular tumor mass A well circumscribed accumulation of contrast medium within a tangle of regular vessels almost giving the impression of homogeneous filling of the mass is seen (Figs 4 5) It does not however approach the dense completely homogeneous filling as in an aneurysm of the carotid artery Since the tumor often nestles between the internal and external carotid arteries these arteries are displaced in a characteristic way The tumor mass is always situated at the bifurcation and receives most of its blood supply from the external carotid artery The vessels embraced by the tumor may be slightly narrowed but are never significantly occluded The common carotid artery proximal to the tumor may be hypertrophied (Figs 3 5 6)

Carotid angiographies were performed on twelve of the thirteen cases in our series (see Table) In eleven cases the characteristic changes were present, in the twelfth case the carotid vessels had been previously ligated and an injection on the normal side failed to fill the tumor side The angiographic preoperative diagnosis was correct in all cases

two years TURNBULL (1954) also reported a case with metastatic spread to lungs Bone metastases have been reported by ANDERSON & SCARCELLA (1963) DONALD & CRILE (1948) reported a case with spread to pelvis, ribs, femur and sternum GOODOF & LISCHER (1943) reported a case with spread to pancreas, and SPOTNITZ (1951) had a case with spread to cervical glands, skin, kidney, pancreas, heart and pleura Other visceral metastases reported include GRONBERGER (1917) spread to kidneys and mediastinum and GILFORD & DAVIS (1904) spread to liver Other reports of malignancy include MORFIT, SWAN & TAYLOR (1953), ROMANSKI (1954), WARREN (1959), MOBERG (1961), REFSE, LUCAS & BERGMAN (1963) and MORRIS et coll (1963)

LE COMPTE (1951) stated that he had never seen a malignant carotid chemodectoma In one case in his series, a node enclosed near the tumor was involved, but this could have been due to direct extension In a case reported by RUSH (1962), local invasion was encountered in the brachial plexus REESE et coll (1963) report 13 instances of regional lymph node involvement and 15 instances of distant dissemination MACCOMB (1948) reported recurrence in nodes in the neck after resection of tumor and AREAN (1955) reported tumor extending into the spinal canal Spread to adjacent lymph glands has also been reported by SHOWAN & OWEN (1938), LAHEY & WARREN (1947), MONRO (1950), GOARMAGHTICH & PATTYN (1954), FRIEDMAN & LAU (1957), RABSON & ELLIOT (1957), and FERNAN ZEGARRA (1957)

Radiology

Apart from a soft tissue mass in the conventional film of the neck, no special changes have been reported in the literature or in our group The changes due to metastases have been excluded Negative or normal findings such as normal intervertebral foramina, and absence of bone erosion are usually observed

Carotid angiography Despite some of the unique physical findings, a correct preoperative diagnosis is often not made according to most authors LAHEY & WARREN (1951) reported 18 patients in whom a correct diagnosis was made in only 9 cases (quoting WETZEL) In the series of 5 cases reported by HAWKINS (1961) a correct diagnosis was made only after carotid angiography In WESTBURY's series (1960), in none of seven cases was a preoperative diagnosis made by the referring surgeon Bilateral angiography performed in three of the cases showed characteristic changes However, MONRO (1950) stated arteriography would appear to play no part in carotid body tumor diagnosis unless it be in the occasional case where the possibility of aneurysm can not be excluded on clinical grounds

Angiography is a most valuable diagnostic aid in the study of carotid chemodectomas (CONLEY 1963) It is usually diagnostic for the medium and the large carotid chemodectomas and is highly suggestive for the smaller ones MORRIS et coll (1963) claimed that angiography provided the most accurate diagnosis before surgery Angiography may establish a diagnosis and may also supply other information such as the size of the tumor its spatial relationship to the common internal and external carotid arteries and a collateral flow from the opposite side via the circle of Willis or extracranial anastomotic channels Lesions higher in the neck and unsuspected lesions on the opposite side may be revealed (ENGSTROM & HAMBERGER 1957)

The first angiographic study of these tumors was reported by LICHTENAUER (1938) following tumor biopsy Since then many reports have appeared (IDBOHRN 1951 WRIGHT 1952 LIPSCHITZ 1958 BORELLI 1959 MYBURGH & BERK 1959 NELSON 1962 and others)

Carotid angiography may be performed by puncturing the common carotid artery directly or introducing a catheter into this vessel from another site of puncture Selective injection into the internal and external carotid arteries may be used When a large mass is encountered, the carotid artery may be punctured in a retrograde direction A dosage of 8—10 ml of contrast medium is usually sufficient Serial films should be taken to demonstrate the filling and emptying of the tumor with contrast medium Carotid angiography of the contralateral side with compression on the carotid artery of the affected side should be performed to demonstrate patency of collateral channels should it become necessary to sacrifice the involved carotid artery

The most common finding on angiography is contrast filling of the vascular tumor mass A well circumscribed accumulation of contrast medium within a tangle of regular vessels almost giving the impression of homogeneous filling of the mass is seen (Figs 4 5) It does not however approach the dense completely homogeneous filling as in an aneurysm of the carotid artery Since the tumor often nestles between the internal and external carotid arteries these arteries are displaced in a characteristic way The tumor mass is always situated at the bifurcation and receives most of its blood supply from the external carotid artery The vessels embraced by the tumor may be slightly narrowed but are never significantly occluded The common carotid artery proximal to the tumor may be hypertrophied (Figs 3 5 6)

Carotid angiographies were performed on twelve of the thirteen cases in our series (see Table) In eleven cases the characteristic changes were present in the twelfth case the carotid vessels had been previously ligated and an injection on the normal side failed to fill the tumor side The angiographic preoperative diagnosis was correct in all cases

Table

Data concerning twelve patients examined by carotid angiography

Case no	Sex	Age	Side of tumor	Length of history (yrs)	Symptoms
1	F	58	Left	12	Mass left neck gradually increasing in size
2	F	23	Left	7	Enlarging mass in left neck
3	F	48	Right	1/2	Swelling of right upper neck
4	F	32	Left	1/4	Mass left neck increasing in size
5	F	33	Left	3	Small gland
6	M	29	Right	5	Painless mass in neck
7	M	61	Left	25	Painless mass increasing in size
8	M	51	Right	5	Painless mass in right neck
9	F	23	Left	1	Mass left neck
10	F	34	Right	4	Painless mass in right neck
11	M	45	Right	1/2	Small mass in right neck
12	F	51	Left	18	Painless mass in left submandibular
13	M	57	Right	3/4	Painless right submandibular mass Paroxysmal hypertension ix years

Case reports

Case 1 This 58 year old woman had been aware of a slowly enlarging painless mass in the left neck for about twelve years Operation elsewhere one year previously had revealed a mass adherent to the carotid vessels which could not be completely extirpated and which biopsy disclosed to be a chemodectoma Physical examination was essentially negative except for the presence of an operative scar in the left cervical region overlying a small firm mass Diagnostic studies including roentgen examination of the chest and skull and an

Table (cont)

Clinical diagnosis	Angiographic diagnosis	Treatment
Carotid chemodectoma	No angiogram	*Excision*
Biopsy previously Carotid chemodectoma (Previous operation)	Rt — Normal Lt — No filling	(1) Resected with carotid ligation 4 yrs previously (2) Excised in toto Fibrotic left internal and external carotid
Aspiration biopsy Schwannoma ganglioma or carotid chemodectoma	Carotid chemodectoma	No operation
P evious *operation* Carotid chemodectoma	Carotid chemodectoma	No operation
Biopsy previously Carotid chemodectoma	Carotid chemodectoma	Excised
Biopsy previously Carotid chemodectoma	Carotid chemodectoma	Excised
Aneurysm	Carotid chemodectoma	No operation
Carotid chemodectoma	Carotid chemodectoma	No operation
Biopsy previously	Carotid chemodectoma	6 000 R (Cobalt) previously Excised
Carotid chemodectoma	Carotid chemodectoma	(1) 9 yrs previously left carotid chemodectoma (2) 6 yrs previously mass resected (3) Right carotid chemodectoma excised
Carotid chemodectoma	Carotid chemodectoma	Excised
Carotid chemodectoma	Carotid chemodectoma	(1) 18 yrs previously right carotid chemodectoma *excised* (2) Left — No operation
Carotid chemodectoma	Carotid chemodectoma	*Operation deferred*

Case 10 had a carotid chemodectoma excised on the left side 9 years previously Six years previously a right glomus jugulare mass was resected A right carotid chemodectoma was removed on her last admission

electrocardiogram were normal At operation a 3 × 2 5 cm mass of rubbery consistency was removed from the carotid bifurcation without complication Histologic examination revealed a chemodectoma

Case 2 A left cervical mass *reported to* be a chemodectoma had been removed from this 23-year-old woman at another hospital seven years prior to admission *Three* years thereafter



Fig 1 Case 7 Carotid angiogram showing a chemodectoma of the carotid bifurcation in a patient previously thought to have a luetic carotid aneurysm Extreme vascularity of the tumor

the mass again became apparent and gradually enlarged She complained of marked local discomfort and pain followed by headache when the tumor site was touched or compressed A pulsatile hard mass horizontally mobile was noted close to the carotid bulb area In the superior end of the overlying long vertical scar of the previous operation a small tender nodule was evident Left carotid angiography revealed no filling presumably because of ligation or resection of the carotid vessels at the previous operation A right carotid angiography was normal with little contrast entering the left anterior and middle cerebral arteries At operation a 2 5 cm firm mass was removed from the level of the left carotid bifurcation Tiny fibrotic left internal and external carotid arteries were noted Histologic examination was reported as chemodectoma

Case 3 For approximately six months this 48 year old woman had noted a painless mass in the upper right cervical region Examination disclosed a fullness of the right upper neck with apparent displacement of the parotid gland laterally by a tumor approximately 6 × 4 cm involving the deep pharyngeal space at the level of the tonsil Aspiration biopsy through the oral cavity yielded bloody fluid The possibility of a Schwannoma ganglioma or carotid chemodectoma was suggested because of the clinical features of the mass Roentgen examination of the chest and skull were normal A right carotid angiography revealed a dense homogeneous contrast filled area at the right carotid bifurcation with displacement of trachea to left by a mass Angiographic diagnosis of a right carotid chemodectoma was made The patient refused an operation (Fig 3)

Case 4 This 32 year old woman had been aware of a small mass in the left upper neck for about three months Exploratory operation had been performed by her local physician who found a markedly pulsatile mass in the left carotid bifurcation Examination followed transfer



Fig 5 Case 8 Chemodectoma of the carotid bifurcation Characteristic separation of the internal and external carotid arteries by the vascular tumor



Fig 6 Case 9 Chemodectoma of the carotid bifurcation The tumor separates the internal and external carotid arteries

and revealed a markedly pulsatile small mass in the region of the carotid bifurcation which could be displaced horizontally but not vertically Mild diffuse enlargement of the thyroid gland was noted Routine studies including EEG were normal A left carotid angiography revealed a vascular mass in the bifurcation of the carotid artery Operation was deferred (Fig 3)

Case 5 About three years previously this 33 year-old woman consulted her physician because of an earache Examination at that time disclosed a small left cervical gland Subsequently operation and biopsy of this site was carried out about three months prior to admission at which time diagnosis of a carotid chemodectoma was made Examination on admission disclosed a firm fixed mildly tender left submandibular mass approximately 5 cm in diameter The skin overlying this area contained a well healed linear scar Roentgen examination of the skull and cervical spine were negative EEG was normal Left carotid angiography revealed a vascular mass at the left carotid bifurcation At operation a very vascular soft encapsulated tumor mass (5 4 cm) located at the carotid bifurcation was excised Histologic examination was reported as chemodectoma (Figs ? 3)

Case 6 A mass in the right upper cervical region was noted five years earlier during a routine pre-employment examination of this ?9 year old man A biopsy a year ago had disclosed the presence of a chemodectoma Examination revealed a mild nasal quality to his voice weakness of right lateral gaze a bulging mass in the right lateral pharynx and mild narrowing of the right palpebral fissure Roentgen examination of the cervical spine was negative Chest film was normal except for tracheal deviation to the left at the base of the neck Right carotid angiography disclosed a vascular mass in the carotid bifurcation At operation a vascular



Fig 7 Case 10 Chemodectoma of the right carotid bifurcation and of the right glomus jugulare Patient had a chemodectoma of the left carotid bifurcation removed 9 years previously

encapsulated mass approximately 6 × 4 cm which extended superiorly and medially producing bulging of right lateral pharyngeal wall was excised Histologic examination reported chemodectoma (Fig 3)

Case 7 This 61 year old man first noted a swelling of the left neck about twenty five years previously This was believed to an aneurysm and attributed to syphilis which he had contracted some 18 years earlier Repeated courses of anti luetic therapy were given but his blood serology remained persistently positive Two courses of roentgen treatment of the cervical mass as well as further anti luetic drug treatment were given two years after the mass was discovered CSF examination at that time was entirely normal Thereafter he received further anti luetic treatment including penicillin on several occasions his most recent being two years prior to admission The mass in the left neck continued to grow and reached the size of a plum It was pulsatile firm movable horizontally and unassociated with a *bruit* Finger compression of the carotid artery or mass did not affect the patient adversely Skull and chest films were normal EKG was normal EEG was borderline Blood serology was positive (2 +) Carotid angiography revealed a large vascular mass separating the internal and external carotid arteries and extending up to base of the skull The angiogram was considered to be typical for a carotid chemodectoma Operation was deferred (Figs 3 4)

Case 8 While wrestling with his young son this 51 year old man became aware of local pain in the right neck which persisted several hours He had been aware of a painless firm



a b

Fig 8 Aneurysm of the internal carotid artery which presented as a mass in the nasopharynx Calcified margin of the aneurysm seen in (a)

mass in the right upper neck for several years He had also known of gout for several years Examination was objectively unremarkable except for the firm right cervical mass freely movable and approximately 3 cm in diameter Films of the skull were normal Cervical spine films disclosed arthritic changes with marked narrowing of C6—7 interspace and straightening of cervical spine EEG was borderline with mild left occipital dysfunction Right common carotid angiography disclosed a tumor stain at the bifurcation of the common carotid artery with separation of the internal and external carotid arteries without narrowing of their lumina The appearance was considered characteristic of a carotid chemodectoma Operation was deferred (Figs 3 5)

Case 9 On a routine examination one year previously this 23 year-old woman was found to have a small firm mass in the left neck Two biopsies were made elsewhere and a diagnosis of angiosarcoma made following which she received 6 000 R (Cobalt) to the neck with reduction in size of the mass Examination on admission revealed a hoarse voice dysphagia of mild grade and a firm mass in the left neck where the skin and subcutaneous tissue were tough and fibrous in the area that had been irradiated Skull and chest films and EEG were normal A left carotid angiography disclosed a vascular mass approximately 7 × 4 cm in diameter in the carotid bifurcation extending up to base of skull At operation a massive tumor extending into the left nasopharyngeal region was excised Histologic report was chemodectoma Figs 3 6



Fig 7 Case 10 Chemodectoma of the right carotid bifurcation and of the right glomus jugulare Patient had a chemodectoma of the left carotid bifurcation removed 9 years previously

encapsulated mass approximately 6 × 4 cm which extended superiorly and medially producing bulging of right lateral pharyngeal wall was excised Histologic examination reported chemodectoma (Fig 3)

Case 7 This 61 year old man first noted a swelling of the left neck about twenty five years previously This was believed to an aneurysm and attributed to syphilis which he had contracted some 18 years earlier Repeated courses of anti luetic therapy were given but his blood serology remained persistently positive Two courses of roentgen treatment of the cervical mass as well as further anti luetic drug treatment were given two years after the mass was discovered CSF examination at that time was entirely normal Thereafter he received further anti luetic treatment including penicillin on several occasions his most recent being two years prior to admission The mass in the left neck continued to grow and reached the size of a plum It was pulsatile firm movable horizontally and unassociated with a bruit Finger compression of the carotid artery or mass did not affect the patient adversely Skull and chest films were normal EKG was normal EEG was borderline Blood serology was positive (2 +) Carotid angiography revealed a large vascular mass separating the internal and external carotid arteries and extending up to base of the skull The angiogram was considered to be typical for a carotid chemodectoma Operation was deferred (Figs 3 4)

Case 8 While wrestling with his young son this 51 year old man became aware of local pain in the right neck which persisted several hours He had been aware of a painless firm



Fig 9 Cervical neurofibroma Catheter introduced in retrograde direction down the carotid artery Displacement of the carotid artery in a smooth curve Absence of tumor vessel

Differential diagnosis

Laterally situated single mobile tumors of the neck include branchial cysts carotid chemodectomas neurofibromas and metastatic lesions from the thyroid gland (LAHEY) To these must be added aneurysms of the carotid artery enlarged glands (tuberculosis infection lymphomas) parotid tumors and giant cell arteritis (PEARSE & HINSHAW 1956)

Aneurysms Aneurysms of the carotid artery in the neck are rare when compared with aneurysms elsewhere and when present may mimic a carotid chemodectoma Extracranial aneurysms of the carotid artery have been reported by HARDIN (1961) HALASZ & KENNADY (1964) SPERLING & VIEHWEGER (1963) WYCHULIS BEAHRS & BERNATZ (1964) BUXTON STEVENSON & STAFLWORTH (1964) BYRNE (1958) reported a case of a mass in the neck which was wrapped with nylon mesh in the mistaken diagnosis of an aneurysm The mass later increased in size and a carotid chemodectoma was found to be present

WETZEL (1957) reported a case which was thought to be an aneurysm but which subsequently was found to be a carotid chemodectoma MONRO (1950)

Case 10 This 34 year old woman had a left submaxillary mass removed nine years previously, at which time it was reported to be a carotid chemodectoma Over the next three year period an infiltrating right glomus jugulare chemodectoma was twice resected subtotally She was readmitted to hospital because of the new finding of a growing mass in the right upper anterior part of the neck associated with mild local pains and a drawing sensation in the neck On examination a small plum size firm non tender mass was noted in the region of the right carotid bifurcation In addition there were residuals of effects of her right glomus jugulare tumor and previous operations (right hemi atrophy of tongue hoarse voice, deviation of palate to right difficulty in swallowing solids diplopia on right lateral gaze and bilateral deafness — greater on right) Right carotid angiography disclosed a vascular mass in the right carotid bifurcation At operation a 3 × 3 cm mass was removed from the right carotid bifurcation Histologic report was chemodectoma (Figs 3, 7)

Case 11 This 45 year old man was asymptomatic except for the presence of a painless mass in the right neck at the level of the carotid bifurcation for six months Examination revealed a small firm non tender mass in the region of the right carotid bifurcation which was movable horizontally but not vertically Routine examinations including EKG EEG were normal Right carotid angiography disclosed a vascular mass at the carotid bifurcation This was subsequently resected and removed along with portions of the right external carotid artery Histologic report was chemodectoma (Fig 3)

Case 12 A right carotid chemodectoma present for 10 years had been previously removed 18 years ago from a 51 year old woman Shortly thereafter she noted a similar small painless firm mass in the left upper cervical region which grew slowly over the years to its current larger size Occasionally while lying in bed she would perceive a regular pounding or pulsation in the mass area She mentioned that her father also had a similar large mass in the left side on his neck which was considered to be a carotid chemodectoma by her referring physician She stated that following the removal of her right carotid chemodectoma she had lost her voice for 8 months and that following a thyroidectomy 11 years ago she again lost her voice for 18 months On examination a firm non tender peach sized mass was present in the left submandibular area and could be freely moved horizontally but not vertically A bruit was audible over the tumor zone The mass bulged slightly into the left nasopharynx Two well healed linear surgical scars were present in the neck — a vertical one in the region of the right carotid bifurcation and a horizontal one in the suprasternal area Routine EKG and EEG were normal A selective left carotid angiography via an axillary catheter disclosed a large vascular mass at the bifurcation of the left common carotid artery with separation and displacement of the carotid arteries The angiographic appearance was considered to be characteristic of carotid chemodectoma Operation was deferred (Figs 3)

Case 13 This 57 year old man had visited several medical centers because of paroxysmal hypertension during the previous six years A cause for this hypertension was not established On occasion the possibility of a pheochromocytoma was raised but not definitely confirmed About 8 months before admission he noted a painless mass in the right submandibular area Physical examination disclosed a plum size firm mass in the right pharynx with displacement of the tonsil and pillar anteromedially A right carotid angiography revealed a highly vascularized mass in the right carotid bifurcation separating the internal and external carotid arteries and supplied by branches of the vertebral artery

and do not demonstrate the angiographic appearance of a carotid chemodectoma A primary growth elsewhere may suggest the diagnosis such as a single metastasis from a carcinoma of the thyroid gland

Parotid tumors These occur usually in the third or fourth decade and may take years to develop They are usually firm, hard and painless Sialography may be helpful in the differential diagosis (BECKER 1964)

Acknowledgement

We wish to thank Dr John J Conley Chief of Head & Neck Service St Vincent s Hospital & Medical Center of New York who referred many of the patients including all those with chemodectomas for diagnostic evaluation and angiography

SUMMARY

The clinical and angiographic features associated with chemodectomas of the carotid bifurcation have been reviewed and our experiences including 13 patients with this disease are presented The usefulness and role of angiography in the differential diagnosis of cervical masses in the region of the carotid bifurcation is demonstrated

ZUSAMMENFASSUNG

Die Verfasser haben eine Übersicht uber die klinischen und angiographischen Symptome die mit Chemodectom der Karotisbifurkation verbunden sind gemacht Ihre Erfahrungen einschliesslich 13 Patienten mit dieser Krankheit werden vorgelegt Der Wert und die Rolle der Angiographie fur die Differentialdiagnose der Tumoren in Bezirk der Karotisbifurkation werden demonstriert

RÉSUMÉ

Les auteurs ont passé en revue les signes cl niques et angiographiques des chemodectomes de la b furcation carotidienne et présentent leurs 13 cas personnels Ils montrent l utilité de l angiographie pour le dia nostic différentiel des tumeurs cervicales de la région de la bifurcation carotidienne

BIBLIOGRAPHY

ALBERS C D Branchial anomalies J Amer med Ass 186 (1963) 399

ANDERSON R and SCARCELLA J V Carotid body tumors Amer J Surg 106 (1963) 856

ANICHKOV S V and BELENKII M L Pharmacology of the carotid body ch moreceptors Translated by Dr R Crawford p 225 MacMillan 1963

AREAN V M Recurrent carotid body tumor Arch Path 60 (1955) 530

– and DE ARELLANO C A R Intra abdominal non-chromaffin paraganglioma Ann Surg 144 (1956) 133

ASKENASY H M EPPENSTEIN S S and HERZBERGER E E Tumors of the glomus jugulare co-existing po s bly with carotid body tumor Acta neurochir 3 (1953) 170

reported a case of carotid ligation for an aneurysm which turned out to be a carotid chemodectoma. LIPSCHITZ (1958) distinguished between a highly vascular tumor and an aneurysm. An angiography revealed a carotid chemodectoma.

Angiomas and other vascular tumors of the neck may bear some similarity to the angiographic appearance of carotid chemodectomas. These rarely displace vessels and usually present no difficulty in the clinical diagnosis of the case.

Case 7 in our series was admitted with the diagnosis of an aneurysm. His history went back many years. A gradually expanding mass in the neck was considered an aneurysm. He had a positive serology for syphilis and had many courses of treatment. Angiography revealed a carotid chemodectoma (Fig. 4). Two other cases, not included in our series but admitted with the diagnosis of carotid chemodectoma, had an aneurysm of the carotid artery and a tortuous vessel respectively. A carotid angiography made the distinction immediately. One case admitted to us with a mass in the neck had calcification in the wall of the aneurysm (Fig. 8).

Branchial cysts. These may occur at the level of the carotid bifurcation and may be mistaken for carotid chemodectomas. They are inclined to be more superficial and are usually below the level of the carotid bifurcation. They rarely bulge into the pharynx and can be moved in a horizontal and vertical plane. A detailed history including embryonic developmental abnormalities, a barium swallow with contrast medium and cinefluoroscopy will usually help make the diagnosis (ALBERS 1963).

Neurofibroma. These may arise from any of the cervical nerves and may be extremely difficult to distinguish from carotid chemodectomas, particularly if they happen to grow between the internal and the external carotid arteries which may be separated. If they arise from a nerve which has a vertical disposition then vertical movement will be limited. These tumors are usually immobile and enlarge the exit foramina of the spine. Evidence of masses elsewhere should be sought as well as the other stigmata of neurofibromatosis. Although neurofibromas may be associated with increased vascularity, the angiographic appearance in no way resembles a carotid chemodectoma (Fig. 9).

Lymph nodes. Neoplastic or infected nodes may sometimes cause difficulty in the differential diagnosis. Calcification may be seen in tuberculous glands. Lymph nodes rarely separate the internal and the external carotid arteries

and do not demonstrate the angiographic appearance of a carotid chemodectoma A primary growth elsewhere may suggest the diagnosis such as a single metastasis from a carcinoma of the thyroid gland

Parotid tumors These occur usually in the third or fourth decade and may take years to develop They are usually firm hard and painless Sialography may be helpful in the differential diagosis (BECKER 1964)

Acknowledgement

We wish to thank Dr John J Conley Chief of Head & Neck Service, *St Vincent s Hospital* & Medical Center of New York who referred many of the patients including all those with chemodectomas for diagnostic evaluation and angiography

SUMMARY

The clinical and angiographic features associated with chemodectomas of the carotid bifurcation have been reviewed and our experiences including 13 patients with this disease are presented The usefulness and role of angiography in the differential diagnosis of cervical masses in the region of the carotid bifurcation is demonstrated

ZUSAMMENFASSUNG

Die Verfasser haben eine Übersicht uber die klinischen und angiographischen Symptome die mit Chemodectom der Karotisbifurkation verbunden sind gemacht Ihre Erfahrungen *einschliesslich 13 Patienten mit dieser Krankheit werden vorgelegt Der Wert und die Rolle* der Angiographie fur die Differentialdiagnose der Tumoren in Bezirk der Karotisbifurkation *werden demonstriert*

RÉSUMÉ

Les auteurs ont passé en revue les signes cliniques et angiographiques des chemodectomes de la bifurcation carotidienne et présentent leurs 13 cas personnels Ils montrent l utilité d l angiographie pour le diagnostic différentiel des tumeurs cervicales de la région de la *bifurcation* carotidienne

BIBLIOGRAPHY

ALBERS C D Branchial anomalies J *Amer med Ass 186 (1963) 399*

ANDERSON R and SCARCELLA J V Carotid body tumors Amer J Surg 106 (1963) 856

ANICHKOV S V and BELENKII M L Pharmacology *of the carotid body* chemoreceptors Translated by Dr R Crawford) p 275 MacMillan 1963

AREAN V M Recurrent carotid body tumor Arch Path 60 (1955) 530

— and DEARELLANO G A R Intra abdominal non chromaffin paraganglioma Ann Surg 144 1956 1 3

ASKENASY H M EPPENSTEIN S S and HERZBERGER E E Tumors of the glomus jugulare co-existing possibly with carotid body tumor Acta neurochir 3 (1953) 170

reported a case of carotid ligation for an aneurysm which turned out to be a carotid chemodectoma LIPSCHITZ (1958) distinguished between a highly vascular tumor and an aneurysm An angiography revealed a carotid chemodectoma

Angiomas and other vascular tumors of the neck may bear some similarity to the angiographic appearance of carotid chemodectomas These rarely displace vessels and usually present no difficulty in the clinical diagnosis of the case

Case 7 in our series was admitted with the diagnosis of an aneurysm His history went back many years A gradually expanding mass in the neck was considered an aneurysm He had a positive serology for syphilis and had many courses of treatment Angiography revealed a carotid chemodectoma (Fig 1) Two other cases, not included in our series but admitted with the diagnosis of carotid chemodectoma, had an aneurysm of the carotid artery and a tortuous vessel respectively A carotid angiography made the distinction immediately One case admitted to us with a mass in the neck had calcification in the wall of the aneurysm (Fig 8)

Branchial cysts These may occur at the level of the carotid bifurcation and may be mistaken for carotid chemodectomas *They are inclined to be more* superficial and are usually below the level of the carotid bifurcation They rarely bulge into the pharynx and can be moved in a horizontal and vertical plane A detailed history including embryonic developmental abnormalities, a barium swallow with contrast medium and cinefluoroscopy will usually help make the diagnosis (ALBERS 1963)

Neurofibroma These may arise from any of the cervical nerves and may be extremely difficult to distinguish from carotid chemodectomas, particularly if they happen to grow between the internal and the external carotid arteries which may be separated If they arise from a nerve which has a vertical disposition, then vertical movement will be limited These tumors are usually immobile and enlarge the exit foramina of the spine Evidence of masses elsewhere should be sought as well as the other stigmata of neurofibromatosis Although neurofibromas may be associated with increased vascularity, the angiographic appearance in no way resembles a carotid chemodectoma (Fig 9)

Lymph nodes Neoplastic or infected nodes may sometimes cause difficulty in the differential diagnosis Calcification may be seen in tuberculous glands Lymph nodes rarely separate the internal and the external carotid arteries

HEYMANS C, BOUCKAERT J J et DAUTREBANDE L Sinus carotidien et reflexes respiratoires Arch int Pharmacodyn 39 (1930) 400

IDBOHRN H Angiographic diagnosis of carotid body tumors Acta radiol 35 (1951) 115

KIPKIE G F Simultaneous chromaffin tumors of the carotid body and the glomus jugulare Arch Path 44 (1947) 113

KROLL A J ALEXANDER B COCHIOS F and PECHET L Hereditary deficiencies of clotting factors VII and X associated with carotid body tumors New Engl J Med 278 (1964) 6

LADENHEIM J C and SACHS E JR Familial tumors of the glomus jugulare Neurology II (1961) 303

LAHEY F H and WARREN K W Tumors of the carotid body Surg Gynec Obstet 85 (1947) 281

— — Long term appraisal of carotid body tumors with remarks on their removal Surg Gynec Obstet 92 (1951) 481

LATTES R Non-chromaffin paraganglioma of ganglion nodosum carotid body and aortic arch bodies Cancer 3 (1950) 667

— MACDONALD J J and SPROUL E Non-chromaffin paraganglioma of carotid body and orbit report of a case Ann Surg 139 (1954) 382

LECOMPTE P M Tumors of the carotid body and related structures (chemoreceptor system) Atlas of Tumor Pathology Armed Forces Institute of Pathology Wash D C 1951

LEWISON E F and WEINBERG T Carotid body tumors Surgery 27 (1950) 437

LICHTENAUER F Operationsindikation und Arteriographie bei Carotisdrusengeschwulsten Zbl Chir 65 (1938) 2286

LIPSCHITZ R Angiographic study of a carotid body tumor Brit J Radiol 31 (1958) 105

MACCOMB W S Carotid body tumors Ann Surg 127 (1948) 269

MACDONALD R A A carotid body like tumor on the left subclavian artery Arch Path 62 (1956) 107

MARCHAND F Beitrage zur kenntniss der normalen und pathologischen anatomie der glandula carotica Festschr f Virchow (1891) 1535

MARTORELL F Tumor of the carotid body Angiology 7 (1956) 278

MCILRATH D C and REMINE W H Carotid body tumors Surg Clin N Amer 43 (1963) 1135

MIROV A C Benign and malignant carotid body tumors J Amer med Ass 181 (1962) 13

MOBERG A Malignant carotid body tumor with metastasis in lungs Acta otolaryng 53 (1961) 590

MONRO R S The natural history of carotid body tumors and their diagnosis and treatment with a report of five cases Brit J Surg 37 (1950) 445

MORFIT H M SWAN H and TAYLOR E R Carotid body tumors Report of twelve cases including one case with proved visceral dissemination A M A Arch Surg 67 (1953) 194

MORRIS G C JR BALAS P E COOLEY D A CRAWFORD E S and DEBAKEY M E Surgical treatment of benign and malignant carotid body tumors Amer Surg 29 (1963) 429

MULLIGAN R M Chemodectoma in the dog Amer J Path 26 (1950) 680

MYBURGH J A and BERK M E Carotid body tumors S Afr med J 33 (1959) 329

NELSON W R Carotid body tumors Surgery 51 (1962) 326

OBERHOLZER R J H and TOFANI W C The Handbook of Physiology Vol 2 p 1123 Williams & Wilkins Baltimore 1960

PEARSE H F and HINSHAW J P Bilateral arteritis simulating carotid body tumors Surg Gynec Obstet 103 1956 263

BECKER W Parotid tumors, diagnosis differential diagnosis therapy Physicians Panorama 2 (1964) 25
BIRRELL J H W Carotid body tumors a study of three cases including a bilateral example Aust N Z J Surg 22 (1952) 123
BORELLI G Aspetti angiografici dei tumori del glomo carotideo Radiol med 45 (1959) 250
BOYD J D The development of the human carotid body Contributions to Embryology Vol 26, p 3 Carnegie Institute 1937
BURMAN S O The vagal body tumor Ann Surg 141 (1955), 488
— The chemoreceptor system and its tumor — the chemodectoma Int Abstr Surg 102 (1956) 330
BUXTON J I STEVENSON T B and STALLWORTH J M Arteriosclerotic aneurysm of the extracranial internal carotid artery treated by excision and primary reanastomosis under controlled hypertension Ann Surg 159 (1964) 222
BYRNE J J Carotid body and allied tumors Amer J Surg 95 (1958) 371
CHASE W H Familial and bilateral tumors of the carotid body J Path Bact 36 (1933) 1
CONLEY J J The management of carotid body tumors Surg Gynec Obstet 12 (1963) 722
— CHUSID J C and SCHECHTER M M Angiography in head and neck surgery Arch Surg 89 (1964) 609
DESAI M G and PATEL C C Heredo familial carotid body tumors Clin Radiol 12 (1961) 21
DONALD R A and CRILE G Tumors of the carotid body Amer J Surg 75 (1948) 435
DUNCAN D K and McDONALD J R Chemodectoma of the mediastinum two cases from right posterior costovertebral sulcus Am J clin Path 21 (1951) 515
Editor Biography of a word J Amer med Ass 187 (1964) 1021
ENGSTROM H and HAMBERGER C A Bilateral tumor of the carotid body Acta otolaryng 48 (1957) 390
FANNING J I WOODS F M and CHRISTIAN H J Metastatic carotid body tumor J Amer med Ass 185 (1963) 129
FERNAN ZEGARRA L Revista di patologia e clinica chirurgica 2 (1957) 171
FISHER E R and HAZARD J B Non chromaffin paraganglioma of the orbit Cancer 5 (1952) 521
FRIEDMAN E N and LAU R Carotid body tumors J Mt Sinai Hosp 24 (1957) 633
GANONG W F Review of Medical Physiology P 553 Lange Medical Publications 1963
GIFFORD H and DAVIS K L H Potato tumors of neck and their origin as endotheliomata of carotid body with account of three cases Practitioner 73 (1904) 729
GOARMAGHTICH N and PATTYN S A presumably benign tumor and a proved malignant tumor of the carotid body Amer J Path 30 (1954) 679
GOODOF I I and LISCHER C L Tumor of carotid body and pancreas Arch Path 35 (1943) 906
GRONBERGER G Sarcoma of carotid gland Hygiea 79 (1917) 169
HALASZ N A and KENNEDY J C Excision of arteriosclerotic aneurysms of the cervical internal carotid artery J Neurosurg 21 (1964) 352
HARDIN C A Carotid body tumors and aneurysms Angiology 12 (1961) 597
HARRINGTON S W CLAGETT O T and DOCKERTY M B Tumors of the carotid body Clinical and pathologic considerations of twenty tumors affecting 19 patients (one bilateral) Ann Surg 114 (1941) 820
HAWKINS T D Glomus jugulare and carotid body tumors Clin Radiol 12 (1961) 199

AUS DEM STRAHLENINSTITUT DER UNIVERSITAT DES SAARLANDES HOMBURG/SAAR,
DEUTSCHLAND

MORPHOLOGICAL CHANGES OF THE BRAIN FOLLOWING INTRATHECAL APPLICATION OF CONTRAST MEDIA

by

REINHARD SCHOBER

Positive contrast media are still used in many countries for ventriculography as well as for myelography Numerous reports of complications have however been published (adhesive arachnoiditis brain nerve damage blindness (3 6 9 12)) When iodized oil was succeeded by iodized esters like Pantopaque such complications did not disappear in examinations of the spinal and intracranial spaces (2 5 10 13, 14) In spite of all efforts the contrast medium can never be completely removed In ventriculography it can not be prevented from reaching the cisterns unless there is a complete occlusion This is even more likely to happen in myelo encephalography with Pantopaque as MONES & WERMAN (1959) have pointed out here the removal of the contrast medium is absolutely impossible

It seems rather strange, under these circumstances that quite recently publications from Latin countries have reported on 1 280 and 3 000 ventriculo graphies using iodized oil (MORETE de PARDAL & PARDAL 1958 DILENGE et coll 1961) In Germany and the Scandinavian countries its use has been

PETTET J R, WOOLNER L B and JUDD E S Carotid body tumors (chemodectomas) Ann Surg 157 (1953), 465

PHELPS F W CASE S W and SNYDER G A C Primary tumors of carotid body review of 159 histologically verified cases, report of a case West J Surg 45 (1937) 42

RABSON A S and ELLIOT J L Carotid body tumors with regional lymph node involvement with report of a case Surgery 42 (1957) 381

RANDALL K J and WALTER J B Metastasizing non chromaffin paraganglioma of thigh J Path Bact 67 (1954), 69

REESE H F LUCAS R N and BERGMAN P A Malignant carotid body tumors Ann Surg 157 (1963) 232

RIEGNER Cited by Byrne J J (1958) 377

ROMANSKI R Chemodectoma (non chromaffin paraganglioma) of carotid body with distant metastases Amer J Path 30 (1954), 1

ROSS I L Electron microscopic observations of the carotid body of the cat Biophys Biochem & Cytol 6 (1959) 253

RUSH B I Current concepts on the treatment of carotid body tumors Surgery 52 (1962) 679

SCHADE R Tumors of the glomus jugulare and glomus caroticum Brit J Cancer 7 (1953) 440

SESSIONS R T McSWAIN B CARLSON R I and SCOTT H Surgical experiences with tumors of the carotid body glomus jugulare and retroperitoneal non chromaffin paraganglia Ann Surg 150 (1959) 808

SHOWAN H K and OWEN C I Carotid body tumors Amer J Surg 40 (1938) 462

SMETANA H F and SCOTT W F JR Malignant tumors of non chromaffin paraganglia Milit Med 109 (1951) 330

SPERLING M and VIEHWEGER G Extracranial aneurysms of the internal carotid artery and their treatment Chirurg 34 (1963), 369

SPOTNITZ M Case of malignant tumor of carotid body with multiple metastases Oncologia 4 (1951) 239

SUTTON D Angiography Livingstone 1962

TAYLOR G G On carotid tumors Brit J Surg 28 (1940) 163

TURNBULL F M JR Malignancy in carotid body tumors with presentation of a proved case of metastasis to the lungs West J Surg 62 (1964) 382

UVNAS B Central cardiovascular control Handbook of Physiology Vol 2 p 1131 Williams & Wilkins Baltimore Md 1960

VON HALLER Cited by DICKINSON A M and FRAVER C A Carotid body tumors Review of the literature with a report of 2 cases Amer J Surg 69 (1945) 9

WARREN K W Some observations on carotid body tumors Surg Clin N Amer 39 (1959) 621

WESTBURY G The management of carotid body tumors with a report of 7 cases Brit J Surg 47 (1960) 605

WETZEL N Carotid angiography in diagnosis and treatment of tumors of the neck A M A Arch Surg 74 (1957) 954

WOSNESSENKI Cited by TAYLOR G G (1940)

WRIGHT I B A case of carotid body tumor investigated by angiography J Fac Radiol 3 (1952), 290

WYCHULIS A R BEAHRS O H and BERNATZ P F Aneurysm of internal carotid artery treated by excision and anastomosis to external carotid artery A M A Arch Surg 88 (1964) 803

AUS DEM STRAHLENINSTITUT DER UNIVERSITAT DES SAARLANDES HOMBURG/SAAR
DEUTSCHLAND

MORPHOLOGICAL CHANGES OF THE BRAIN FOLLOWING INTRATHECAL APPLICATION OF CONTRAST MEDIA

by

REINHARD SCHOBER

Positive contrast media are still used in many countries for ventriculography as well as for myelography Numerous reports of complications have however, been published (adhesive arachnoiditis brain nerve damage blindness (3 6 9 12)) When iodized oil was succeeded by iodized esters like Pantopaque such complications did not disappear in examinations of the spinal and intracranial spaces (2 5 10 13 14) In spite of all efforts the contrast medium can never be completely removed In ventriculography it can not be prevented from reaching the cisterns unless there is a complete occlusion This is even more likely to happen in myelo encephalography with Pantopaque as MONES & WERMAN (1959) have pointed out here the removal of the contrast medium is absolutely impossible

It seems rather strange under these circumstances that quite recently, publications from Latin countries have reported on 1 280 and 3 000 ventriculo graphies using iodized oil (MORETE de PARDAL & PARDAL 1958 DILENGE et coll 1961) In Germany and the Scandinavian countries its use has been



Fig 1

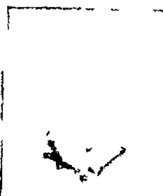


Fig 2

Fig 1 Position of the contrast medium in the basal cisterns

Fig 2 Eighteen weeks after injection On the removed brain the contrast medium is partly fixed to the leptomeninx

restricted, while it is more frequently used in the United States and Great Britain

Although there have been numerous clinical reports of complications and results of autopsies or biopsies of pathological changes after the use of Pantopaque within the cerebrospinal fluid spaces, no experimental work has been done The authors therefore started experiments on rabbits

Three possibilities for the application of the contrast medium were at hand

1 Puncture of the great cistern, with this technique it is difficult to pass the contrast medium into the skull cavity without its flowing off into the spinal canal

2 Puncture of the ventricular system this has the disadvantage of unavoidable traumatic brain damage and hence a changed situation for the assessment of the lesions

3 Trephination of the skull cap in the frontal area with a ball drill and injection of the contrast medium through a tiny perforation of the dura into the subarachnoid space of the convexity The last mentioned method was used, since with this technique trauma is avoided

An amount of 0 1 ml/kg was injected, that is, 0 3 ml on an average per animal Roentgen ray control showed that the contrast medium flowed quickly down into the area of the basal cisterns and remained there (Fig 1)

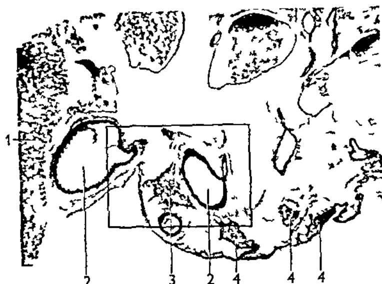


Fig 3 S x weeks afte injection Densification of the arachnoidal meshwork w th plaques in the cisterna ch asmatis 1 Tractus opticus 2 Carotis interna 3 Pa aga gl on carot cum 4 Arachnoidal cell cones Hematoxylin-eos n ×4?

Thus the same situation as in ventriculography and myelography was created

The animals were under observation for up to 4 1/2 months There were no side effects The contrast medium did not change position or extension during this period and later roentgen control only showed the droplets in closer formation a sign of sealing-off

The removal of the brain at weekly intervals was in some cases not so easy as in untreated animals After the brain had been carefully lifted from the anterior fossa adhesions were to be seen even macroscopically Even the dura normally fixed to the bone came away Pantopaque flowed out from the opened cisterns Radiograms of the removed and fixed brain showed traces of contrast medium within the basal cisterns apparently adherent to the menin geal tissue (Fig 2)

In all cases the histological examination revealed the same findings although they differed in intensity according to the duration of the test The arachnoidea consisted of a visceral endothelial layer connected with the pia and a parietal layer in connection with the dura A filamentous meshwork extended be tween them Bedlike proliferation areas had developed on these endothelial layers which amalgamated to form cell cones Undoubtedly the perivascular tissue of the neighbouring pia vessels had taken part in developing these cell cones They were a formation of rather large epithelial cells which both

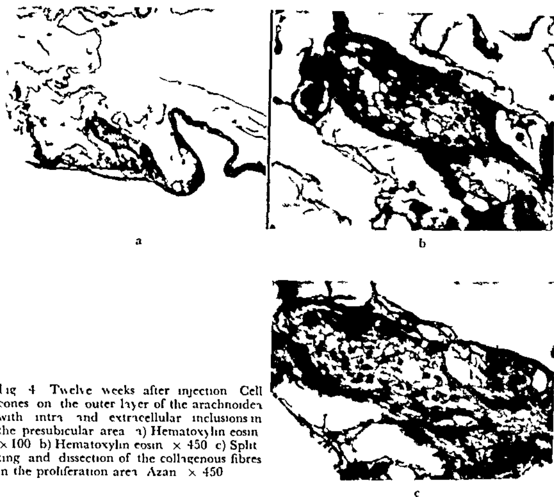


Fig. 4. Twelve weeks after injection. Cell cones on the outer layer of the arachnoidea with intra- and extracellular inclusions in the presubicular area. a) Hematoxylin eosin × 100. b) Hematoxylin eosin × 450. c) Splitting and dissection of the collagenous fibres in the proliferation area. Azan × 450.

intracellularly and extracellularly had some small droplike inclusions. Sometimes large cavities within the meshwork could be seen — undoubtedly the places from which the oily contrast medium was resolved during the preparation of the tissue slides (Figs 3 and 4).

For the demonstration of the collagenous fibres Azan dye was used. They were found to be dissected and fragmented within the area of the cell plaques and cell cones. An increase in the collagenous fibres and densification of the arachnoidal meshwork were also seen (Figs 4c and 5).

It should be stressed that the changes observed were not inflamed granulation tissue; they completely lacked participation by the capillaries. They were a proliferative mesenchymal reaction with intra- and extracellular inclusions, fibre dissection and fibre increase. It was an adhesive process. As reported in some cases in humans, genuine granulation tumors apparently develop under special conditions. They depend on the consistence of the cerebrospinal fluid,



Fig 5 Eighteen weeks after injection Arachnoidal proliferation area in the cisterna chiasmatis showing increase conglomeration and splitting of the collagenous fibres Azan × 100

admixture of blood and so on (2 13) None of these circumstances were present in our experiment

The initial damage is caused by slow decomposition of the iodine esters liberating free fatty acids here the undecyl acid which saponifies with the potassium of the CSF This causes a chronic irritation It is difficult to say how far the iodine separated from the molecule could also be responsible for these reactions In any case it can only cause an effect in elementary form and not as an ion The diminishing of the Pantopaque depots which is said to take place in humans at a rate of 1 ml per year is due according to several statements (HURTEAU et coll 1954) to iodine elimination and not to true resorption of the carrier molecule which remains in the same place

According to the results of the experiment the use of iodine esters within the cerebrospinal fluid spaces is not without risk Whether or not the arachnoidal adhesions become efficient from the clinical point of view depends solely on the localisation of the rest depot of the contrast medium and therefore is absolutely accidental The risks are probably less in the spinal area than in the vicinity of the brain especially of the cranial nerves where such adhesive changes may lead to serious dysfunction Consequently, the use of substances that are neither resorbable nor removable is inadvisable As long as there is not an absolutely indifferent contrast medium for the examination of these

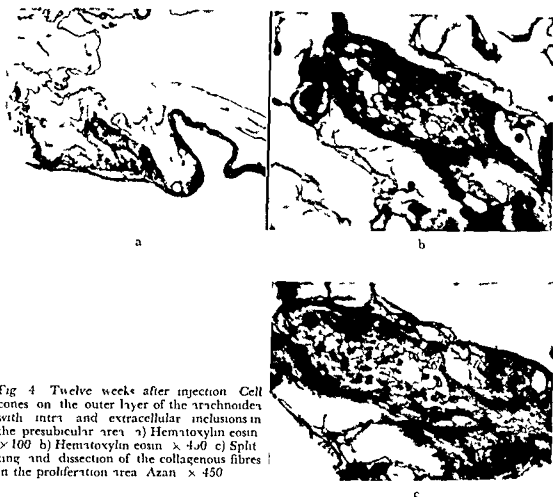


Fig 4 Twelve weeks after injection Cell cones on the outer layer of the arachnoidea with intra and extracellular inclusions in the presubicular area a) Hematoxylin eosin × 100 b) Hematoxylin eosin × 450 c) Splitting and dissection of the collagenous fibres in the proliferation area Azan × 450

intracellularly and extracellularly had *some small droplike inclusions* Sometimes large cavities within the meshwork could be seen — undoubtedly the places from which the oily contrast medium was resolved during the preparation of the tissue slides (Figs 3 and 4)

For the demonstration of the collagenous fibres Azan dye was used They were found to be dissected and fragmented within the area of the cell plaques and cell cones An increase in the collagenous fibres and densification of the arachnoidal meshwork were also seen (Figs 4c and 5)

It should be stressed that the changes observed were not inflamed granulation tissue, they completely lacked participation by the capillaries They were a proliferative mesenchymal reaction with intra and extracellular inclusions, fibre dissection and fibre increase It was an adhesive process As reported *in* some cases *in humans, genuine granulation tumors* apparently develop under special conditions They depend on the consistence of the cerebrospinal fluid,



Fig 5 Eighteen weeks after inject on Arachnoidal proliferation area in the cisterna chiasmatis sho ing increase conglomeration and splitting of the collagenous fibres Azan × 100

admixture of blood and so on (2, 13) None of these circumstances were present in our experiment

The initial damage is caused by slow decomposition of the iodine esters, liberating free fatty acids here the undecyl acid which saponifies with the potassium of the CSF This causes a chronic irritation It is difficult to say how far the iodine separated from the molecule could also be responsible for these reactions In any case it can only cause an effect in elementary form and not as an ion The diminishing of the Pantopaque depots which is said to take place in humans at a rate of 1 ml per year, is due, according to several statements (HURTEAU et coll 1954), to iodine elimination and not to true resorption of the carrier molecule which remains in the same place

According to the results of the experiment the use of iodine esters within the cerebrospinal fluid spaces is not without risk Whether or not the arachnoid al adhesions become efficient from the clinical point of view depends solely on the localisation of the rest depot of the contrast medium and therefore is absolutely accidental The risks are probably less in the spinal area than in the vicinity of the brain especially of the cranial nerves, where such adhesive changes may lead to serious dysfunction Consequently the use of substances that are neither resorbable nor removable is inadvisable As long as there is not an absolutely indifferent contrast medium for the examination of these

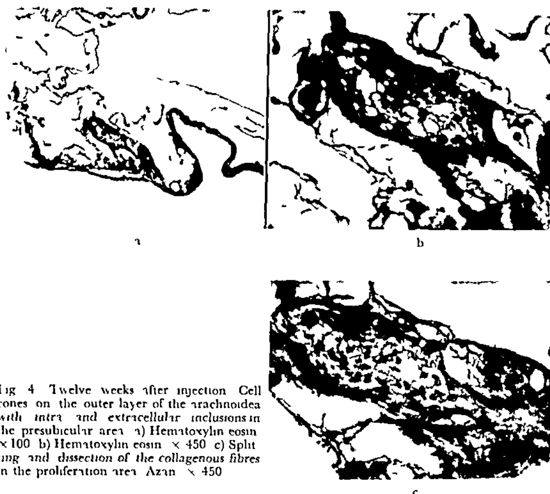


Fig. 4. Twelve weeks after injection. Cell cones on the outer layer of the arachnoidea *with intra- and extracellular inclusions in* the presubicular area. a) Hematoxylin eosin ×100. b) Hematoxylin eosin × 450. c) Split*ting and dissection of the collagenous fibres* in the proliferation area. Azan × 450

intracellularly and extracellularly had some small droplike inclusions. Sometimes large cavities within the meshwork could be seen — undoubtedly the places from which the oily contrast medium was resolved during the preparation of the tissue slides (Figs. 3 and 4).

For the demonstration of the collagenous fibres Azan dye was used. They were found to be dissected and fragmented within the area of the cell plaques and cell cones. An increase in the collagenous fibres and densification of the arachnoidal meshwork were also seen (Figs. 4c and 5).

It should be stressed that the changes observed were not inflamed granulation tissue; they completely lacked participation by the capillaries. They were a proliferative mesenchymal reaction with intra- and extracellular inclusions, fibre dissection and fibre increase. It was an adhesive process. As reported in some cases in humans, genuine granulation tumors apparently develop under special conditions. They depend on the consistence of the cerebrospinal fluid,

intracerebral vessels seemed noticeable at this time This fact may be due to an increased exchange of substance and fluid between brain tissue and cerebro spinal fluid space or blood vessels

Although during these seizures a specially high demand for energy is being put upon the brain there is no damage to the producers of the energy con nected with it Damage as such will only be caused by cerebral hypoxemia due to disregulation of breathing and of the circulatory system during the seizures Under general anesthesia brain damage due to cerebral hypoxemia may as shown above be avoided

SUMMARY

Experiments on rabbits after injection of iodine esters in the intracranial fluid spaces showed after several weeks proliferative mesenchymal reactions of the arachnoidea with intra and extracellular inclusions and dissection and increase in fibres Their use for diag nostic purposes is therefore not without risks The resorption of water soluble contrast media does not cause morphological changes in the brain The practical use of these substances is reduced since they cause seizures that can only be avoided by general anesthesia

ZUSAMMENFASSUNG

Injektion von Jodestern in die intracraniellen Liquorraume von Kaninchen bestatige nach einigen Wochen das Auftreten von proliferativen mesenchymalen Reaktionen der Arachnoidea mit intra und extrazellularen Einschlussen Zerteilung und Zunahme der Fasern Ihre Anwendung fur diagnostische Zwecke ist deshalb nicht ohne Risiko Die Resorb tion von wasserloslichen Kontrastmittel verursacht keine morphologischen Gehirnverande rungen Die praktische Anwendung dieser Substanzen fur diagnostische Zwecke ist einge schrankt da sie Krampfe verursachen die nur mit Allgemeinanasthesie verhindert werden können

RÉSUMÉ

L injection expérimentale chez des lapins d esters iodés dans les espaces liquidiens intra craniens a été suivie au bout de plusieurs semaines de réactions prolifératives du mésenchyme de l arachnoide avec inclusions intra et extracellulaires dissection et augmentation du nombre des fibres Leur emploi pour le diagnostic n est donc pas sans danger La résorption des moyens de contraste hydrosolubles ne cause pas de modifications morphologiques du cerveau L utilisation pratique de ces substances est reduite car elles causent des crises convulsives qu on ne peut éviter que par anesthésie générale

REFERENCES

1 DILENGE D DAVID M und TALAIRACH J Zur Indikation und Technik der Jodventri kulographie Neuro-chirurgie 6 (1961) 347

2 ERICKSON T C and van BAAREN H J Late meningeal reaction to ethyl iodophenyl undecylate used in myelography J Amer med Ass 153 (1953) 636

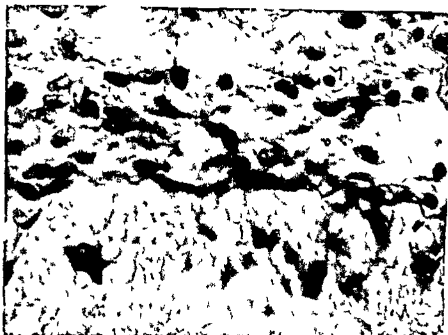


Fig. 6. Two days after injection of water soluble contrast medium. Widening of the subpial glia chambers with cell infiltrates in pia and arachnoidea (area precentralis). Hematoxylin eosin × 450

sensitive areas we must rely on air, which in most cases gives enough information to the skilled examiner.

Further examinations were performed with resorbable contrast media (diatrizoate). After the injection of 0.12 ml/kg (Urografin 60 %) into the fluid space the animals reacted with spasms and died. On the other hand, a 5 % NaCl solution was well tolerated. Thus, hypertonia, which is higher in the NaCl solution, was not the important factor in causing the spasms.

After injection of the contrast medium under general anesthesia no unusual reactions were observed. The anesthesia extends the time of resorption of the contrast medium to at least 2 hours, however. The spasm producing tendency of the solution may be lessened in this way, and the amount can even be doubled without damage.

These brains were examined histologically at intervals of up to 4 weeks after injection. They revealed neither damage of the ganglion cells nor progressive or regressive reactions of the glia that could indicate perishing of neurons. Only during the first days was loosening of the fine reticular tissue of the pia and cell infiltrates seen (Fig. 6). However, these lesions were quickly reversible and were also seen in animals that received Ringer's solution alone.

Widening of the subpial glia chambers and periadventitial spaces of the

intracerebral vessels seemed noticeable at this time This fact may be due to an increased exchange of substance and fluid between brain tissue and cerebro spinal fluid space or blood vessels

Although during these seizures a specially high demand for energy is being put upon the brain there is no damage to the producers of the energy connected with it Damage as such will only be caused by cerebral hypoxemia due to disregulation of breathing and of the circulatory system during the seizures Under general anesthesia brain damage due to cerebral hypoxemia may as shown above be avoided

SUMMARY

Experiments on rabbits after injection of iodine esters in the intracranial fluid spaces showed after several weeks proliferative mesenchymal reactions of the arachnoidea with intra and extracellular inclusions and dissection and increase in fibres Their use for diagnostic purposes is therefore not without risks The resorption of water soluble contrast media does not cause morphological changes in the brain The practical use of these substances is reduced since they cause seizures that can only be avoided by general anesthesia

ZUSAMMENFASSUNG

Injektion von Jodestern in die intracraniellen Liquorraume von Kaninchen bestatigt *nach* einigen Wochen das Auftreten von proliferativen mesenchymalen Reaktionen der *Arachnoidea* mit intra und extrazellularen Einschlussen Zerteilung und Zunahme der Fasern Ihre Anwendung fur diagnostische Zwecke ist deshalb nicht ohne Risiko Die Resorbtion von *wasserloslichen* Kontrastmittel verursacht keine morphologischen Gehirnverande rungen. Die praktische Anwendung dieser Substanzen fur diagnostische Zwecke ist einge schrankt *da sie* Krampfe verursachen die nur mit Allgemeinanasthesie verhindert werden konnen

RÉSUMÉ

L injection experimentale chez des lapins d esters iodés dans les espaces liquidiens intra craniens a *été suivie* au bout de plusieurs semaines de réactions proliferatives du mésenchyme de l arachnoide *avec inclusions* intra et extracellulaires dissection et augmentation du nombre des fibres. Leur emploi pour le diagnostic n est donc pas sans danger La résorption des moyens de contraste *hydrosolubles* ne cause pas de modifications morphologiques du cerveau L utilisation pratique de ces substances est réduite car elles causent des crises convulsives qu on ne peut éviter que par anesthésie *générale*

REFERENCES

1 DILENGE D DAVID M und TALAIRACH J Zur Indikation und Technik der Jodventri kulographie Neuro-chirurgie 6 (1961) 347

2 ERICKSON T C and van BAAREN H J Late meningeal reaction to ethyl iodophenyl undecylate used in myelography J Amer med Ass 153 (1953) 636

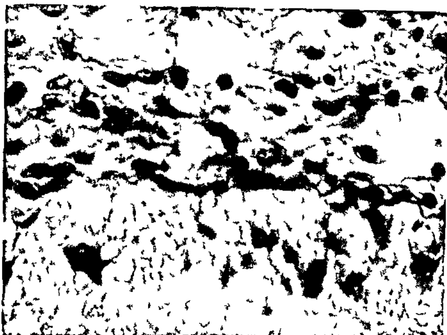


Fig. 6. Two days after injection of water soluble contrast medium. Widening of the subpial glia chambers with cell infiltrates in pia and arachnoidea (area precentralis). Hematoxylin eosin × 450.

sensitive areas we must rely on air, which in most cases gives enough information to the skilled examiner.

Further examinations were performed with resorbable contrast media (diatrizoate). After the injection of 0.12 ml/kg (Urografin 60 %) into the fluid space the animals reacted with spasms and died. On the other hand, a 5 % NaCl solution was well tolerated. Thus, hypertonia, which is higher in the NaCl solution, was not the important factor in causing the spasms.

After injection of the contrast medium under general anesthesia no unusual reactions were observed. The anesthesia extends the time of resorption of the contrast medium to at least 2 hours, however. The spasm producing tendency of the solution may be lessened in this way, and the amount can even be doubled without damage.

These brains were examined histologically at intervals of up to 4 weeks after injection. They revealed neither damage of the ganglion cells nor progressive or regressive reactions of the glia that could indicate perishing of neurons. Only during the first days was loosening of the fine reticular tissue of the pia and cell infiltrates seen (Fig. 6). However, these lesions were quickly reversable and were also seen in animals that received Ringer's solution alone.

Widening of the subpial glia chambers and periadventitial spaces of the

FROM THE DEPARTMENT OF RADIOLOGY THE RADCLIFFE INFIRMARY OXFORD
ENGLAND

SAFER CAROTID ANGIOGRAPHY BY PERCUTANEOUS CANNULATION

by

PHILIP SHELDON

The greatest danger of carotid angiography lies in the possibility of dissection of the wall of the artery by the point of the needle thus obstructing or reducing the intracranial blood flow (Fig 1) SALTZMAN suggested that this complication occurred in 10 % of patients examined there was no reason to suppose that our experience with needle angiography differed from his SCHEINBERG & ZUNKER (1963) found intramural injections in 60 % of patients undergoing carotid angiography who later exhibited complications which in their series of 500 patients arose in 3 7 % of examinations and included 3 deaths Catheterisation (LIVERUD 1958 ELVIN 1960 AMUNDSEN, DIETRICHSEN ENGE & WILLIAMSON 1963 and SCHECHTER 1963) and teflon cannulation (SOILA 1963) are alternative methods which have been suggested to avoid this danger The purpose of this paper is to describe another technique which we think is far easier to perform than catheterisation or teflon cannulation greatly increases the safety of the operation compared with needle angiography and permits selective injection of the internal or external carotid arteries almost at will

The instrument (Fig 2) which has been in use since October 1962, is a short

3 HOFMANN A Die Bedeutung der Rontgendiagnostik fur die operative Behandlung des Bandscheibenprolapses Fortschr Röntgenstr 73 (1950), 412
4 HURTEAU E F BAIRD W C and SINCLAIR C Arachnoiditis following the use of iodized oil J Bone Jt Surg 36A (1954), 393
5 LUCE J C LEITH W and BURRAGE W S Pantopaque meningitis due to sensitivity Radiology 57 (1951), 878
6 MIFKA P Über Komplikationen der Myelographie Wien klin Wschr (1949), 700
7 MONES R and WERMAN R Pantopaque myeloencephalography Radiology 72 (1959) 803
8 MORICE de PARDAL M L et PARDAL F Mise au point de l iodoventriculographie Acta radiol 50 (1958), 34
9 PANTER K Die Kontrastmitteldarstellung der spinalen Raume Fortschr Neurol Psychiat 23 (1955) 173
10 PEACHER W G and ROBERTSON R C L Pantopaque myelography Results comparison of contrast media and spinal fluid reaction J Neurosurg 2 (1945) 220
11 RALSTON B L GROSS S W and NEWMANN E W Pantopaque ventriculography in the localisation of surgical lesions of the posterior fossa Amer J Roentgenol 81 (1959) 972
12 RODRIGUEZ de MATA T Un caso de amaurosis total y transitoria consecutiva a una inyección intrarraquides de lipiodol Acta Soc cir Madrid 2 (1933) 165
13 TARLOV I M Pantopaque meningitis disclosed at operation J Amer med Ass 129 (1945) 1014
14 WINKELMANN N W GOTTEN N and SCHELBERT D Localised adhesive arachnoiditis Study of 25 cases with reference to etiology Trans Amer neurol Ass 78 (1953) 15

FROM THE DEPARTMENT OF RADIOLOGY THE RADCLIFFE INFIRMARY OXFORD
ENGLAND

SAFER CAROTID ANGIOGRAPHY BY PERCUTANEOUS CANNULATION

by

PHILIP SHELDON

The greatest danger of carotid angiography lies in the possibility of dissection of the wall of the artery by the point of the needle thus obstructing or reducing the intracranial blood flow (Fig 1) SALTZMAN suggested that this complication occurred in 10 % of patients examined there was no reason to suppose that our experience with needle angiography differed from his SCHEINBERG & ZUNKER (1963) found intramural injections in 60 % of patients undergoing carotid angiography who later exhibited complications which in their series of 500 patients arose in 3 7 % of examinations and included 3 deaths Catheterisation (LIVERUD 1958 ELVIN 1960 AMUNDSEN DIETRICHSEN ENGE & WILLIAMSON 1963 and SCHECHTER 1963) and teflon cannulation (SOILA 1963) are alternative methods which have been suggested to avoid this danger The purpose of this paper is to describe another technique which we think is far easier to perform than catheterisation or teflon cannulation greatly increases the safety of the operation compared with needle angiography and permits selective injection of the internal or external carotid arteries almost at will

The instrument (Fig 2) which has been in use since October 1962 is a *short*



Fig 1 Angiograms showing almost complete obstruction by a small intramural deposit of contrast material during angiography with a conventional needle a) Arterial phase b) Two seconds later c) Arterial phase a few minutes later after puncture lower in the neck (Courtesy Brit J Radiol)

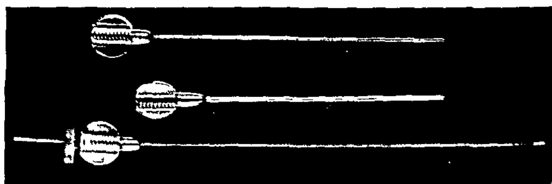


Fig 2 From above Trochar cannula and guide wire held by adjustable chuck (Courtesy Brit J Radiol)

thin walled cannula made of 18 SWG metal tubing containing a sharp trochar Inside diameter is greater than 0 95 mm, and thus accommodates a Seldinger 160 guide wire (SELDINGER 1953) The guide wire we use is 15 cm long and is held by an adjustable chuck (SHELDON 1964)

The artery is punctured in the usual way by transfixing both walls and withdrawing the cannula after removal of the trochar Since we are usually anxious to obtain films of the internal carotid artery distribution without overlying confusing external carotid branches and dilution of contrast (LINDGREN 1947,



Fig 3 Selective cannulation of xternal carot d art ry E en though the orig n of the external carotid artery does not appear pr p tious cannulation wa asily carried out

Wickbom 1948) we find it best to make the puncture at the bifurcation of the common carotid artery The cannula may then be passed into the internal or external arteries (Fig 3) after a small preliminary injection to exclude stenosis or atheromatous roughening and to show how the vessels lie Cannulation is done by inserting the guide wire through the cannula so that its flexible tip projects by 2 or 3 cm and then either sliding the cannula up the guide wire or passing the two up together The cannula should not be passed without the guide wire in position since abrasion or other damage to the wall may be caused

It is obvious that the guide wire must be handled delicately and with care, its use is better avoided if a preliminary injection shows roughening of the arterial wall Some objection may be raised that it may be dangerous to pass a guide wire in the region of the carotid bifurcation, but in only one patient has there been a neurological complication which could be ascribed to use of the guide wire and in this case an obvious contraindication in the form of a large cauliflower like plaque on the posterior arterial wall was ignored this under lines the necessity for obtaining a film of the region of the carotid bifurcation especially in elderly patients



Fig 4 Tip of cannula is hard against posterior wall Even in this poor position no dissection has occurred which a needle would almost certainly have caused A puncture nearer the bifurcation would have been more satisfactory (Courtesy Brit J Radiol)

While internal carotid puncture with a needle may often be a difficult and tedious procedure, with the cannula the internal carotid artery has been cannulated in virtually every case during at least the past eighteen months unless contra indicated NEW & BAKER (1963) recently described a similar cannula, but theirs does not seem to allow any facility for easy and safe selective cannulation

Our cannula has been in use in more than 3 000 examinations Evidence of injection of contrast material into the arterial wall has fallen, so that this occurrence is now only seen once in every 150 to 200 angiograms Similarly the number of complications recorded in our patients is extremely low compared with many published series, due, we believe to lack of damage to the vessel wall (although even when needle angiography used to be carried out we were never greatly troubled by complications) Other advantages over the conventional needle are that the head may be moved with impunity for various projections, and adjustments to the cannula are very rarely needed (Fig 4) while beginners learn the technique as easily as with a needle, but with far greater safety for the patient

While the polythene catheter must obviously be more versatile than a cannula the cannula has the advantage of simplicity, and has small dimensions, since it is only 1 20 mm in diameter, compared with 1 60 mm of the PE 160 polythene catheter Only one manoeuvre is needed to insert it in the artery, and there is no need to replace the cannula by a blunt polythene catheter

which must cause additional trauma to the arterial wall Dissection can also occur with polythene catheterisation The technique is no more difficult than conventional needling which is another great advantage compared with catheterisation

Compared with teflon cannulation the cannula which the present author uses has the advantage that it cannot kink or corrugate when passed through the skin or vessel wall In addition a teflon cannula being easily bent often cannot be directed for selective cannulation

Acknowledgements

I am grateful to Dr F H Kemp for his advice and help in the preparation of this paper The instruments described are made for the author by N J Millard Ltd 36 Highgate Hill London N 19

SUMMARY

A small but useful contrivance for angiography has been described it as simple to use is more versatile and far safer than a needle In the interests of the patients safety and comfort during carotid angiography it is considered that use of the needle should be discontinued

ZUSAMMENFASSUNG

Es wird eine kleine jedoch nutzliche Anordnung fur Carotisangiographie beschrieben Sie ist einfach in der Anwendung vielseitiger und bei weitem sicherer als als eine Nadel die im Interesse der Sicherheit und Bequemlichkeit fur den Patienten nicht mehr angewendet werden sollte

RÉSUMÉ

L auteur décrit un petit perfectionnement instrumental pour l angiographie d emploi simple et beaucoup moins dangereux qu une aiguille Il pense que pour la sécurité et le confort du malade pendant l angiographie on devrait abandonner l emploi de l aiguille

REFERENCES

AMUNDSEN P DIETRICHSEN P ENGE I and WILLIAMSON R Cerebral angiography by catheterization Acta radiol 10 (1963) 164

ELVIN P Angiography of the carotid artery with catheter technique Radiology 75 (1960) 80

LINDGREN E Technique of direct (percutaneous) cerebral angiography Brit J Radiol 75 (1947) 326

LIVERUD K Occluding dissecting aneurysm as a complication of carotid angiography J Oslo City Hospital 8 (1958) 209

NEW P F J and BAKER E Technique for arterial puncture J Neurosurg 20 (1963) 390



Fig 4 Tip of cannula is hard against posterior wall Even in this poor position no dissection *has occurred which a needle would almost certainly have caused* A puncture nearer the bifurcation would have been more satisfactory (Courtesy Brit J Radiol)

While internal carotid puncture with a needle may often be a difficult and tedious procedure, with the cannula the internal carotid artery has been cannulated in virtually every case during at least the past eighteen months unless contra indicated NEW & BAKER (1963) recently described a similar cannula, but theirs does not seem to allow any facility for easy and safe selective cannulation

Our cannula has been in use in more than 3 000 examinations Evidence of injection of contrast material into the arterial wall has fallen, so that this occurrence is now only seen once in every 150 to 200 angiograms Similarly the number of complications recorded in our patients is extremely low compared with many published series, due, we believe, to lack of damage to the vessel wall (although even when needle angiography used to be carried out we were never greatly troubled by complications) Other advantages over the conventional needle are that the head may be moved with impunity for various projections, and adjustments to the cannula are very rarely needed (Fig 4) while beginners learn the technique as easily as with a needle, *but* with far greater safety for the patient

While the polythene catheter must obviously be more versatile than a cannula, the cannula has the advantage of simplicity, and has small dimensions, since it is only 1 20 mm in diameter, compared with 1 60 mm of the PE 160 polythene catheter Only one manoeuvre is needed to insert it in the artery, and there is no need to replace the cannula by a blunt polythene catheter

FROM THE DIVISION OF NEUROLOGICAL SURGERY, THE CARDIOVASCULAR RESEARCH INSTITUTE, AND THE DEPARTMENT OF RADIOLOGY, THE UNIVERSITY OF CALIFORNIA SCHOOL OF MEDICINE, SAN FRANCISCO, CALIF., U.S.A.

VESSEL CALIBER AND CIRCULATION TIME AT CEREBRAL ANGIOGRAPHY IN MONKEYS UNDERGOING HYPOTHERMIA

by

M. C. SMITH, T. H. NEWTON and K. PEARSON

The reaction of cerebral vessels to hypothermia has been obscured under both clinical and experimental conditions by factors of viscosity and ventilation (1, 2, 3, 4). The viscosity of blood is increased as it is cooled in the course of hypothermia, resulting in an increased resistance to flow. Because of the lowered metabolic rate, respiration continued at normal rates under hypothermic conditions markedly lowers the arterial pCO_2, constricting the cerebral vessels. Cerebral blood flow, therefore, may be decreased in the hypothermic state both by cerebrovascular constriction and increased blood viscosity.

Our purpose in this study was to determine the effects of hypothermia per se on the caliber of the cerebral vessels and on the circulation time while viscosity and arterial pCO_2 were carefully controlled. Vascular response to changes of the arterial pCO_2 in the hypothermic state was also studied. The monkey was chosen for these experiments because its cerebral circulation is similar to that of man. Vessel caliber and circulation time were measured using angiographic techniques.

Saltzman G I Angiographic demonstration of the posterior communicating and posterior cerebral arteries Acta radiol 52 (1959), 1

Schechter M Percutaneous carotid catheterization Acta radiol 1 (1963) 417

Scheinberg P and Zunker E Complications in direct percutaneous carotid angiography Arch Neurol 8 (1963) 676

Seldinger S I *Catheter replacement of the needle in percutaneous arteriography* Acta radiol 39 (1953) 368

Sheldon P Percutaneous cannulation of the carotid artery Brit J Radiol 37 (1964) 526

Soila P Introduction of a soft cannula into the carotid artery by percutaneous puncture Acta radiol 1 (1963) 451

Wickbom I Cerebral angiography Acta radiol Suppl 72 (1948)

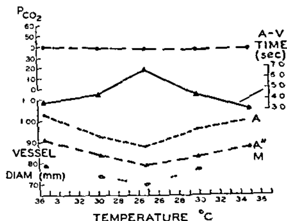


Fig 2 Effect of cooling and rewarming on vessel size and circulation time during maintenance of normal pCO

an automatic injector At intervals of 0 7 sec 10 films were obtained with a Sanchez Perez film changer The calibers of the anterior cerebral and middle cerebral arteries were measured by projection techniques These measurements were made in the inferior and superior portions of the pericallosal artery and in the middle cerebral artery near the trifurcation These sites have been designated A_1 A_2 and M respectively (Fig 1) Arteriovenous circulation time was measured from filling of the carotid siphon to filling of the internal cerebral vein The experimental animals were divided into three groups

Group I (normal arterial pCO_2) Angiograms were obtained in ten monkeys at temperatures of 36 C 30 C and 25 C During the rewarming phase further angiograms were obtained at 30° C and 36 C The arterial pCO_2 was kept constant by careful control of ventilation and frequent monitoring of arterial samples Viscosity controlled during the cooling phase by hemodilution with saline was measured on a falling ball viscometer

Group II (low arterial pCO_2) The method of cooling and rewarming in five monkeys was identical to that employed in Group I Viscosity of blood was maintained constant by hemodilution during the cooling phase The arterial pCO_2 was depressed by hyperventilation to levels of 20 mm Hg or below at 36 C 30 C and 25 C and during rewarming at 30° C and 36 C At each of these temperature levels angiograms were made at normal and low arterial pCO levels

Group III (High arterial pCO_2) Six monkeys were given an inhalation mixture of 10 % CO_2 with 90 % O_2 until their arterial pCO reached levels of 60 mm Hg or higher This was carried out at 36 C 30 C and 25° C and

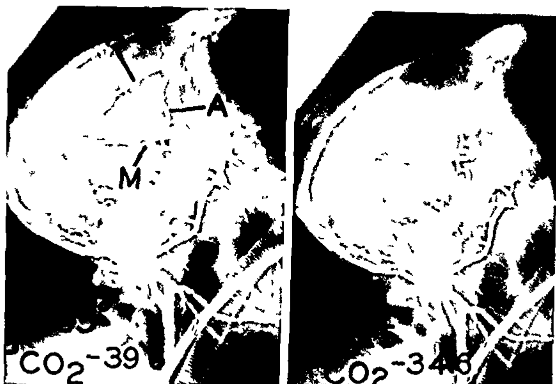


Fig 1 Carotid arteriograms showing notable constriction of major cerebral arteries during hypothermia

Method

Hypothermia was induced in thirty two monkeys (Macacus cynamolgus) by external cooling with ice to temperatures of 25° C Eleven of these monkeys were excluded from the study because of various technical difficulties The cooling period lasted from two to four hours depending on the weight of the monkey, and the animals were then rewarmed to normal temperatures by means of external heat Endotracheal anesthesia was maintained by N O—O inhalation supplemented by intravenous Pentothal® A Bird respirator was used to control exchange of gases Arterial blood pressure was monitored on a Statham strain gauge and recorded on a Grass polygraph The electrocardiogram was continuously monitored Samples of blood were withdrawn through a catheter placed in the right femoral artery for determinations of pCO , O and viscosity Core temperatures were monitored by an esophageal lead A radiopaque polyethylene catheter with an external diameter of 0 047 inch was inserted into the left femoral artery and directed into the proximal right common carotid artery under fluoroscopic control For each angiographic study, 2 ml of 76 % Renografin® were injected through this catheter with

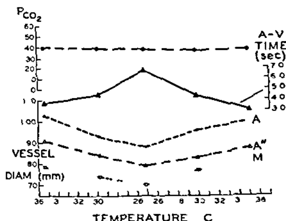


Fig 2 Effect of cooling and rewarming on vessel size and circulation time during maintenance of normal pCO

an automatic injector At intervals of 0 7 sec 10 films were obtained with a Sanchez Perez film changer The calibers of the anterior cerebral and middle cerebral arteries were measured by projection techniques These measurements were made in the inferior and superior portions of the pericallosal artery and in the middle cerebral artery near the trifurcation These sites have been designated A_1 A_2 and M respectively (Fig 1) Arteriovenous circulation time was measured from filling of the carotid siphon to filling of the internal cerebral vein The experimental animals were divided into three groups

Group I (normal arterial pCO_2) Angiograms were obtained in ten monkeys at temperatures of 36 C 30 C and 25 C During the rewarming phase further angiograms were obtained at 30° C and 36 C The arterial pCO_2 was kept constant by careful control of ventilation and frequent monitoring of arterial samples Viscosity controlled during the cooling phase by hemodilution with saline was measured on a falling ball viscometer

Group II (low arterial pCO_2) The method of cooling and rewarming in five monkeys was identical to that employed in Group I Viscosity of blood was maintained constant by hemodilution during the cooling phase The arterial pCO_2 was depressed by hyperventilation to levels of 20 mm Hg or below at 36 C 30 C and 25 C and during rewarming at 30 C and 36° C At each of these temperature levels angiograms were made at normal and low arterial pCO_2 levels

Group III (High arterial pCO) Six monkeys were given an inhalation mixture of 10 % CO_2 with 90 % O_2 until their arterial pCO_2 reached levels of 60 mm Hg or higher This was carried out at 36 C 30° C and 25 C and

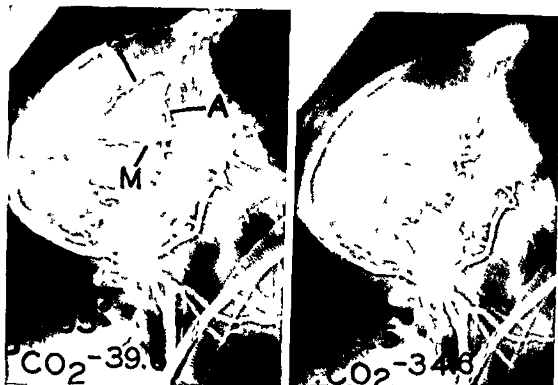


Fig. 1. Carotid arteriograms showing notable constriction of major cerebral arteries during hypothermia.

Method

Hypothermia was induced in thirty two monkeys (Macacus cynamolgus) by external cooling with ice to temperatures of 25° C. Eleven of these monkeys were excluded from the study because of various technical difficulties. The cooling period lasted from two to four hours depending on the weight of the monkey, and the animals were then rewarmed to normal temperatures by means of external heat. Endotracheal anesthesia was maintained by N_2O—O_2 inhalation supplemented by intravenous Pentothal®. A Bird respirator was used to control exchange of gases. Arterial blood pressure was monitored on a Statham strain gauge and recorded on a Grass polygraph. The electrocardiogram was continuously monitored. Samples of blood were withdrawn through a catheter placed in the right femoral artery for determinations of pCO_2, O_2 and viscosity. Core temperatures were monitored by an esophageal lead. A radiopaque polyethylene catheter with an external diameter of 0.047 inch was inserted into the left femoral artery and directed into the proximal right common carotid artery under fluoroscopic control. For each angiographic study, 2 ml of 76 % Renografin® were injected through this catheter with

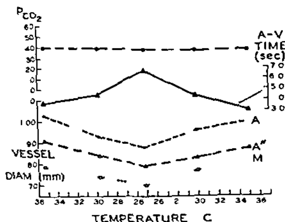


Fig 2 Effect of cooling and re warming on vessel size and circulation time during maintenance of normal pCO

an automatic injector At intervals of 0 7 sec 10 films were obtained with a Sanchez Perez film changer The calibers of the anterior cerebral and middle cerebral arteries were measured by projection techniques These measurements were made in the inferior and superior portions of the pericallosal artery and in the middle cerebral artery near the trifurcation These sites have been designated A_1 A_2 and M respectively (Fig 1) Arteriovenous circulation time was measured from filling of the carotid siphon to filling of the internal cerebral vein The experimental animals were divided into three groups

Group I (normal arterial pCO_2) Angiograms were obtained in ten monkeys at temperatures of 36 C 30 C and 25 C During the rewarming phase further angiograms were obtained at 30 C and 36 C The arterial pCO_2 was kept constant by careful control of ventilation and frequent monitoring of arterial samples Viscosity controlled during the cooling phase by hemodilution with saline was measured on a falling ball viscometer

Group II (low arterial pCO_2) The method of cooling and rewarming in five monkeys was identical to that employed in Group I Viscosity of blood was maintained constant by hemodilution during the cooling phase The arterial pCO_2 was depressed by hyperventilation to levels of 20 mm Hg or below at 36 C 30 C and 25 C and during rewarming at 30 C and 36 C At each of these temperature levels angiograms were made at normal and low arterial pCO_2 levels

Group III (High arterial pCO_2) Six monkeys were given an inhalation mixture of 10 % CO_2 with 90 % O_2 until their arterial pCO_2 reached levels of 60 mm Hg or higher This was carried out at 36 C 30° C and 25° C and

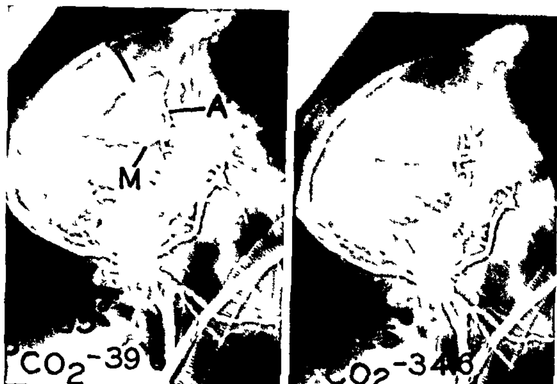


Fig. 1. Carotid arteriograms showing notable constriction of major cerebral arteries during hypothermia.

Method

Hypothermia was induced in thirty two monkeys (Macacus cynamolgus) by external cooling with ice to temperatures of 25° C. Eleven of these monkeys were excluded from the study because of various technical difficulties. The cooling period lasted from two to four hours depending on the weight of the monkey, and the animals were then rewarmed to normal temperatures by means of external heat. Endotracheal anesthesia was maintained by N_2O–O_2 inhalation supplemented by intravenous Pentothal®. A Bird respirator was used to control exchange of gases. Arterial blood pressure was monitored on a Statham strain gauge and recorded on a Grass polygraph. The electrocardiogram was continuously monitored. Samples of blood were withdrawn through a catheter placed in the right femoral artery for determinations of pCO_2, O_2 and viscosity. Core temperatures were monitored by an esophageal lead. A radiopaque polyethylene catheter with an external diameter of 0.047 inch was inserted into the left femoral artery and directed into the proximal right common carotid artery under fluoroscopic control. For each angiographic study, 2 ml of 76% Renografin® were injected through this catheter with

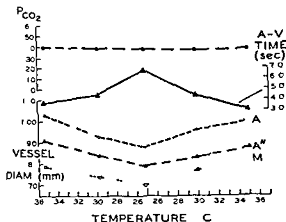


Fig 2 Effect of cooling and rewarming on vessel size and circulation time during maintenance of normal pCO_2.

an automatic injector At intervals of 0 7 sec 10 films were obtained with a Sanchez Perez film changer The calibers of the anterior cerebral and middle cerebral arteries were measured by projection techniques These measurements were made in the inferior and superior portions of the pericallosal artery and in the middle cerebral artery near the trifurcation These sites have been designated A_1 A_2 and M respectively (Fig 1) Arteriovenous circulation time was measured from filling of the carotid siphon to filling of the internal cerebral vein The experimental animals were divided into three groups

Group I (normal arterial pCO_2) Angiograms were obtained in ten monkeys at temperatures of 36 C 30 C and 25 C During the rewarming phase further angiograms were obtained at 30° C and 36 C The arterial pCO_2 was kept constant by careful control of ventilation and frequent monitoring of arterial samples Viscosity controlled during the cooling phase by hemodilution with saline was measured on a falling ball viscometer

Group II (low arterial pCO_2) The method of cooling and rewarming in five monkeys was identical to that employed in Group I Viscosity of blood was maintained constant by hemodilution during the cooling phase The arterial pCO_2 was depressed by hyperventilation to levels of 20 mm Hg or below at 36 C 30 C and 25 C and during rewarming at 30 C and 36 C At each of these temperature levels angiograms were made at normal and low arterial pCO_2 levels

Group III (High arterial pCO) Six monkeys were given an inhalation mixture of 10 % CO_2 with 90 % O_2 until their arterial pCO_2 reached levels of 60 mm Hg or higher This was carried out at 36 C 30° C and 25° C and

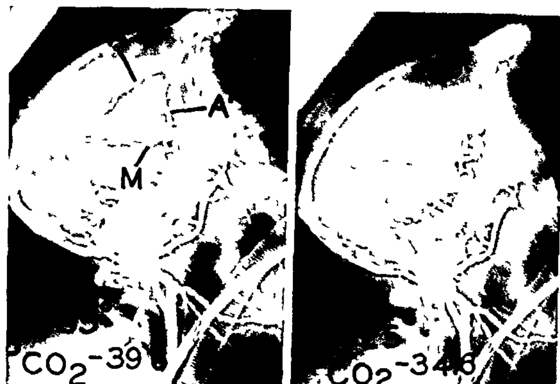


Fig. 1. Carotid arteriograms showing notable constriction of major cerebral arteries during hypothermia

Method

Hypothermia was induced in thirty two monkeys (Macacus cynamolgus) by external cooling with ice to temperatures of 25° C. Eleven of these monkeys were excluded from the study because of various technical difficulties. The cooling period lasted from two to four hours depending on the weight of the monkey, and the animals were then rewarmed to normal temperatures by means of external heat. Endotracheal anesthesia was maintained by N_2O—O_2 inhalation supplemented by intravenous Pentothal®. A Bird respirator was used to control exchange of gases. Arterial blood pressure was monitored on a Statham strain gauge and recorded on a Grass polygraph. The electrocardiogram was continuously monitored. Samples of blood were withdrawn through a catheter placed in the right femoral artery for determinations of pCO_2, O_2 and viscosity. Core temperatures were monitored by an esophageal lead. A radiopaque polyethylene catheter with an external diameter of 0.047 inch was inserted into the left femoral artery and directed into the proximal right common carotid artery under fluoroscopic control. For each angiographic study, 2 ml of 76% Renografin® were injected through this catheter with

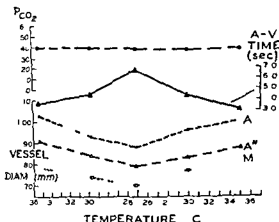


Fig 2 Effect of cooling and rewarming on vessel size and circulation time during maintenance of normal pCO

an automatic injector At intervals of 0 7 sec 10 films were obtained with a Sanchez Perez film changer The calibers of the anterior cerebral and middle cerebral arteries were measured by projection techniques These measurements were made in the inferior and superior portions of the pericallosal artery and in the middle cerebral artery near the trifurcation These sites have been designated A_1 A_2 and M respectively (Fig 1) Arteriovenous circulation time was measured from filling of the carotid siphon to filling of the internal cerebral vein The experimental animals were divided into three groups

Group I (normal arterial pCO_2) Angiograms were obtained in ten monkeys at temperatures of 36 C 30 C and 25 C During the rewarming phase further angiograms were obtained at 30 C and 36 C The arterial pCO_2 was kept constant by careful control of ventilation and frequent monitoring of arterial samples Viscosity, controlled during the cooling phase by hemodilution with saline was measured *on a falling ball viscometer*

Group II (low arterial pCO_2) The method of cooling and rewarming in five monkeys was identical to that employed in Group I Viscosity of blood was maintained constant by hemodilution during the cooling phase The arterial pCO_2 was depressed by hyperventilation to levels of 20 mm Hg or below at 36 C 30° C and 25 C and during rewarming at 30° C and 36 C At each of these temperature levels angiograms were made at normal and low arterial pCO_2 levels

Group III (High arterial pCO_2) Six monkeys were given an inhalation mixture of 10 % CO_2 with 90 % O until their arterial pCO_2 reached levels of 60 mm Hg or higher This was carried out at 36 C 30 C and 25° C and

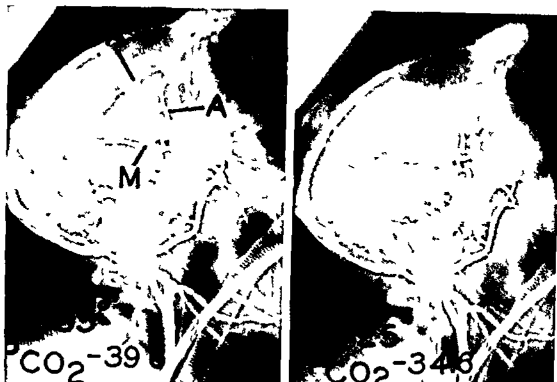


Fig 1 Carotid arteriograms showing notable constriction of major cerebral arteries during hypothermia

Method

Hypothermia was induced in thirty two monkeys (Macacus cynamolgus) by external cooling with ice to temperatures of 25° C Eleven of these monkeys were excluded from the study because of various technical difficulties The cooling period lasted from two to four hours depending on the weight of the monkey, and the animals were then rewarmed to normal temperatures by means of external heat Endotracheal anesthesia was maintained by N_2O—O_2 inhalation supplemented by intravenous Pentothal[R] A Bird respirator was used to control exchange of gases Arterial blood pressure was monitored on a Statham strain gauge and recorded on a Grass polygraph The electrocardiogram was continuously monitored Samples of blood were withdrawn through a catheter placed in the right femoral artery for determinations of pCO_2, O_2 and viscosity Core temperatures were monitored by an esophageal lead A radiopaque polyethylene catheter with an external diameter of 0 047 inch was inserted into the left femoral artery and directed into the proximal right common carotid artery under fluoroscopic control For each angiographic study, 2 ml of 76 % Renografin[R] were injected through this catheter with

mm to 0 88 mm at A_2 from 0 91 mm to 0 79 mm and at M from 0 79 mm to 0 70 mm No significant or consistent hysteretic effect could be observed upon rewarming

The effect of hypothermia on circulation time was even more striking Mean circulation time was 3 9 sec at normal temperature 4 5 sec at 30 C and 6 7 sec at 25 C The circulation time returned to normal upon rewarming

Group II (low arterial pCO_2) The changes in mean size of vessels and in circulation time induced by lowering the pCO_2 levels at varying stages of hypothermia are represented in Fig 3 Lowering of the pCO_2 resulted in a further vasoconstriction and in a prolongation of circulation time at each of the temperature levels Mean measurements at A_1 dropped from 0 95 mm to 0 89 mm at 30 C when the mean arterial pCO_2 was lowered from 38 mm Hg to 15 mm Hg and from 0 87 mm to 0 82 mm at 25° C when the mean arterial pCO was lowered from 37 mm Hg to 14 mm Hg A concomitant prolongation in mean circulation time was observed at 30 C from 4 7 sec to 5 9 sec and at 25 C from 6 1 to 6 6 sec

Group III (high arterial pCO_2) The effects of elevation of pCO_2 levels on mean circulation time and vessel size at varying stages of hypothermia are represented in Fig 4 Elevation of the pCO at all temperature levels resulted in increased vessel size and a more rapid circulation time At 30 C the mean diameter of the pericallosal artery at A_1 was increased from 0 85 mm to 0 95 mm when the pCO_2 was increased from 37 mm Hg to 67 mm Hg At 25 C an increase of the arterial pCO_2 from 38 mm Hg to 56 mm Hg resulted in a mean change at A from 0 79 mm to 0 88 mm Mean circulation time decreased from 5 0 sec to 3 1 sec at 30 C whereas at 25 C it changed from 5 9 sec to 4 1 sec

In two monkeys the effects of prolonged anesthesia of a small catheter in the common carotid artery of repeated exposure to Renografin[R], and of moderate hypotension were studied In neither were the cerebral vessel caliber or circulation time significantly changed

Conclusions

Angiographic measurements showed a consistent constriction of the diameter of the larger cerebral arteries in response to cold despite careful control of viscosity and arterial pCO_2 The slight concomitant drop of systemic blood pressure was shown to have no effect on the caliber of cerebral vessels or the circulation time The percentage decrease of cerebral vessel diameter was 6 to 10 % at 30 C and 11 to 15 % at 25 C compared to the normothermic state Upon rewarming the vessel caliber and circulation time returned to their previous levels

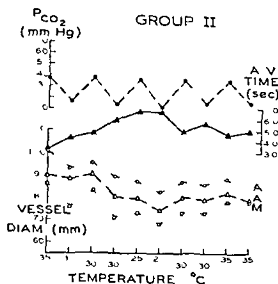


Fig. 3. Effect of lowering pCO_2 levels on circulation time and vessel size during various stages of cooling and rewarming.

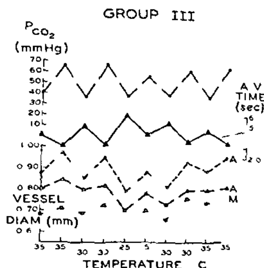


Fig. 4. Effect of elevation of the pCO_2 levels on circulation time and vessel size during various stages of cooling and rewarming.

also, on rewarming, at 30° C and 36° C. Angiograms were obtained at each temperature level at normal and increased arterial pCO_2 levels. Hemodilution was used during the cooling phase to maintain viscosity of the blood at a constant level.

Two additional monkeys were maintained at normal temperature under anesthesia while a series of angiograms comparable to those of the experimental groups were obtained. Arterial blood was then withdrawn until systemic blood pressure dropped 30 mm Hg. This drop corresponded to the mean pressure drop seen at 25° C in the experimental monkeys in *Groups I, II,* and *III*. Angiograms were obtained during the hypotensive period. The blood was then returned to the monkeys and, upon return to normal blood pressure, an angiographic study was again performed.

Results

Group I (normal arterial pCO_2). The changes induced in vessel diameter by hypothermia and by subsequent rewarming while normal pCO_2 and blood viscosity were being maintained are shown in Fig. 2. The caliber of the cerebral vessels was significantly decreased with hypothermia, even under these controlled conditions (Fig. 1) and returned to normal size when the animals were rewarmed.

Between 36° C and 25° C, the mean vessel size at A_1 decreased from 1.03

mm to 0 88 mm, at A_2 from 0 91 mm to 0 79 mm and at M from 0 79 mm to 0 70 mm No significant or consistent hysteretic effect could be observed upon rewarming

The effect of hypothermia on circulation time was even more striking Mean circulation time was 3 9 sec at normal temperature, 4 5 sec at 30 C and 6 7 sec at 25 C The circulation time returned to normal upon rewarming

Group II (low arterial pCO_2) The changes in mean size of vessels and in circulation time induced by lowering the pCO_2 levels at varying stages of hypothermia are represented in Fig 3 Lowering of the pCO_2 resulted in a further vasoconstriction and in a prolongation of circulation time at each of the temperature levels Mean measurements at A_1 dropped from 0 95 mm to 0 89 mm at 30 C when the mean arterial pCO_2 was lowered from 38 mm Hg to 15 mm Hg and from 0 87 mm to 0 82 mm at 25 C when the mean arterial pCO was lowered from 37 mm Hg to 14 mm Hg A concomitant prolongation in mean circulation time was observed at 30 C from 4 7 sec to 5 9 sec and at 25 C from 6 1 to 6 6 sec

Group III (high arterial pCO_2) The effects of elevation of pCO_2 levels on mean circulation time and vessel size at varying stages of hypothermia are represented in Fig 4 Elevation of the pCO_2 at all temperature levels resulted in increased vessel size and a more rapid circulation time At 30 C the mean diameter of the pericallosal artery at A_1 was increased from 0 85 mm to 0 95 mm when the pCO_2 was increased from 37 mm Hg to 67 mm Hg At 25 C an increase of the arterial pCO_2 from 38 mm Hg to 56 mm Hg resulted in a mean change at A_1 from 0 79 mm to 0 88 mm Mean circulation time decreased from 5 0 sec to 3 1 sec at 30 C whereas at 25 C it changed from 5 9 sec to 4 1 sec

In two monkeys the effects of prolonged anesthesia of a small catheter in the common carotid artery of repeated exposure to Renografin®, and of moderate hypotension were studied In neither were the cerebral vessel caliber or circulation time significantly changed

Conclusions

Angiographic measurements showed a consistent constriction of the diameter of the larger cerebral arteries in response to cold despite careful control of viscosity and arterial pCO The slight concomitant drop of systemic blood pressure was shown to have no effect on the caliber of cerebral vessels or the circulation time The percentage decrease of cerebral vessel diameter was 6 to 10 % at 30 C and 11 to 15 % at 25 C compared to the normothermic state Upon rewarming the vessel caliber and circulation time returned to their previous levels

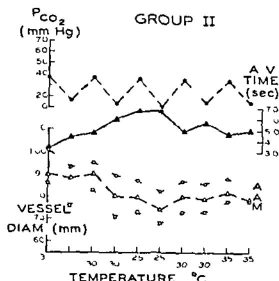


Fig 3 Effect of lowering pCO_2 levels on circulation time and vessel size during various stages of cooling and rewarming

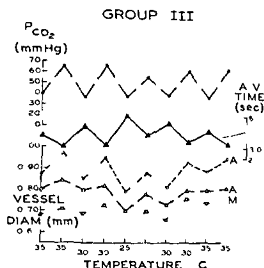


Fig 4 Effect of elevation of the pCO_2 levels on circulation time and vessel size during various stages of cooling and rewarming

also, on rewarming, at 30° C and 36° C Angiograms were obtained at each temperature level at normal and increased arterial pCO levels Hemodilution was used during the cooling phase to maintain viscosity of the blood at a constant level

Two additional monkeys were maintained at normal temperature under anesthesia while a series of angiograms comparable to those of the experimental groups were obtained Arterial blood was then withdrawn until systemic blood pressure dropped 30 mm Hg This drop corresponded to the mean pressure drop seen at 25° C in the experimental monkeys in Groups I, II, and III Angiograms were obtained during the hypotensive period The blood was then returned to the monkeys and, upon return to normal blood pressure, an angiographic study was again performed

Results

Group I (normal arterial pCO) The changes induced in vessel diameter by hypothermia and by subsequent rewarming while normal pCO and blood viscosity were being maintained are shown in Fig 2 The caliber of the cerebral vessels was significantly decreased with hypothermia, even under these controlled conditions (Fig 1) and returned to normal size when the animals were rewarmed

Between 36° C and 25° C, the mean vessel size at A_1 decreased from 1 03

RÉSUMÉ

L effet de l hypothermie sur le calibre des vaisseaux cérébraux et sur le temps de circulation a été étudié par angiographie cérébrale sur 21 singes La pCO_2 la viscosite sanguine et la tension artérielle étaient mesurées A mesure que la température baissait le calibre des vaisseaux cérébraux diminuait et le temps de circulation s allongeait Les modifications de la pCO_2 a basse température la viscosité et la pression sanguine restant constantes donnaient lieu aux mêmes effets physiologiques qu a température normale

REFERENCES

1 BERING JR E A TAREN J A McMURREY J D and BERNHARD W F Studies on hypothermia in monkeys II The effect of hypothermia on the general physiology and cerebral metabolism of monkeys in the hypothermic state Surg Gynec Obstet 102 (1956) 134

2 DILENGE D DAVID M and DILEGNÉ P Angiographic study of cerebral circulation rate during hypothermia Presse Med 7 (1963) 1769

3 GURDJIAN E S THOMAS L M and WEBSTER J E Hypothermia and pial circulation J Neurosurg 17 (1960) 610

4 MEYER J S and HUNTER J Effects of hypothermia on local blood flow and metabolism during cerebral ischemia and hypoxia J Neurosurg 14 (1957) 210

Circulation time was prolonged by hypothermia despite maintenance of constant viscosity Increased arterial pCO levels could overcome this effect The marked slowing of cerebral circulation suggests an increased resistance in the cerebrovascular bed This is probably the result of constriction at the arteriolar level, which could not be measured angiographically

Despite constriction induced by the hypothermic state, an increase in vessel caliber was observed with an increase in the level of arterial pCO Constriction of cerebral vessels induced by cold became more marked when the level of arterial pCO was decreased below normal values

These studies suggest that the common clinical use of hypothermia accompanied by hyperventilation, without hemodilution, may lead to decreased cerebral circulation This slowing of cerebral circulation is of particular importance in situations frequently encountered clinically in which circulation to vital areas may already be impaired Hyperventilation in the hypothermic state may provide ideal operative conditions A more rapid circulation time induced by normal or elevated pCO accompanied by hemodilution, however, may provide better protection of vital areas Perhaps shrinkage of the brain frequently obtained by hyperventilation in the hypothermic state could more safely be obtained by the use of mannitol

Acknowledgement

This study was supported in part by United States Public Health Service Grant NB 04838

SUMMARY

The effect of hypothermia on the size of cerebral vessels and on circulation time was determined in 21 monkeys by means of cerebral angiography The arterial pCO_2 blood viscosity, and blood pressure were controlled The caliber of the cerebral vessels decreased and circulation time was prolonged as the temperature dropped Alteration of the pCO_2 at low temperatures while viscosity and blood pressure were maintained constant resulted in the same physiologic effects as those seen at normal temperatures

ZUSAMMENFASSUNG

Mittels cerebraler Angiographie wurde die Wirkung von Hypertermie auf die Weite der cerebralen Gefasse und Zirkulationszeit bestimmt Es wurden das arterielle pCO_2 die Blutviskositat und der Blutdruck kontrolliert Bei Herabsetzung der Temperatur verringerte sich der Durchmesser der cerebralen Gefasse wahrend die Zirkulationszeit sich verlangerte Veranderungen des pCO_2 bei herabgesetzter Temperatur ergab bei konstanter Viskositat und Blutdruck dieselben physiologischen Wirkungen wie bei normaler Temperatur



Fig 1 A small meningeal branch of the right ophthalmic artery supplies a left frontal parasagittal meningioma Subtraction picture



Fig 2 Right carotid angiography in a patient with a falx meningioma on the left side avascular at left carotid angiography The tumor is supplied by a tentorial branch of the right siphon which running in the free margin of the tentorium crosses the midline to give off tumor vessels at a tumor attachment to the posterior basilar portion of the falx

be kept in mind that the basal dura to a large extent is supplied from the internal carotid artery as is also the dura over the frontal convexity as well as the anterior and the posterior basilar portions of the falx These structures in or close to the midline may normally be supplied by branches from either the ipsi lateral or contra lateral carotid artery and consequently tumors in these areas may also receive their vascular supply from either or both sides Examples of tumor supply from a contra lateral carotid artery are shown in Figs 1 and 2

In our experience a meningeal vascular supply is however not a pathogno monic sign that the lesion is a meningioma since other tumors — even malig nant gliomas — may also receive part of their vascular supply from the meninges A glioma reaching the surface of the brain often infiltrates the over lying dura and will then get part of its supply from dural vessels This seems to be most common in temporal and basal gliomas It is a known fact among

FROM ROENTGENDIAGNOSTIC DEPARTMENT II (DIRECTOR: DOCENT I. WICKBOM),
SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

SIGNIFICANCE OF SOME ANGIOGRAPHIC SIGNS OF INTRACRANIAL MENINGIOMAS

by

STURE STATTIN

Cerebral angiography remains in most cases the best method of differentiating meningiomas from other intracranial expanding lesions and several more or less characteristic angiographic criteria have been advanced by various authors. The most important seem to be: typical vascular displacement, tumor vessels of a characteristic appearance, vascular supply from meningeal vessels, and slow circulation through the tumor as manifestated by the late filling of the drainage veins. We have earlier reported the results from a systematic investigation of the frequency of these criteria (5). In the present paper two of these criteria will be briefly discussed, namely, meningeal vascular supply and tumor circulation time. An attempt will be made to show that to some extent these criteria may be further refined but also that they are not always as pathognomonic as has often been maintained.

When looking for a meningeal vascular supply it is of importance to know that even with apparently avascular tumors it is often possible angiographically to demonstrate small vessels at the dural attachment. Most of them generally arise from the external carotid artery and for that reason separate contrast injection into the external and internal arteries is essential. It should however



Fig 1 A small meningeal branch of the right ophthalmic artery supplies a left frontal parasagittal meningioma Subtraction picture



Fig 2 Right carotid angiography in a patient with a falx meningioma on the left side avascular at left carotid angiography The tumor is supplied by a tentorial branch of the right siphon which running in the free margin of the tentorium crosses the midline to give off tumor vessels at a tumor attachment to the posterior basilar portion of the falx

be kept in mind that the basal dura to a large extent is supplied from the internal carotid artery as is also the dura over the frontal convexity as well as the anterior and the posterior basilar portions of the falx These structures in or close to the midline may normally be supplied by branches from either the ipsi lateral or contra lateral carotid artery and consequently tumors in these areas may also receive their vascular supply from either or both sides Examples of tumor supply from a contra lateral carotid artery are shown in Figs 1 and 2

In our experience a meningeal vascular supply is however not a pathognomonic sign that the lesion is a meningioma since other tumors — even malignant gliomas — may also receive part of their vascular supply from the meninges A glioma reaching the surface of the brain often infiltrates the overlying dura and will then get part of its supply from dural vessels This seems to be most common in temporal and basal gliomas It is a known fact among



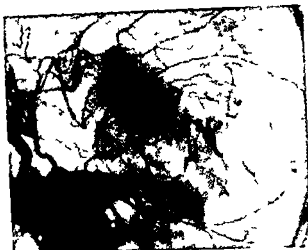
Fig. 3. A malignant glioma in the parietal temporal region has infiltrated the dura and receives part of its blood supply from the external carotid artery. a) Internal carotid angiography. b) External carotid angiography. Arrows point at the draining veins.



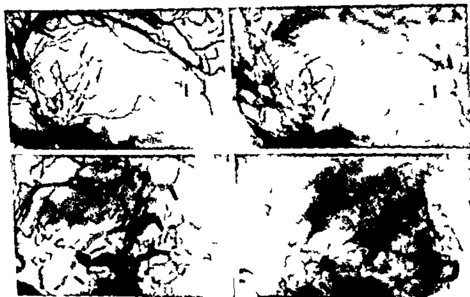
Fig. 4. *Top left.* Internal carotid angiography in a patient with parietal parasagittal glioma adherent to the dura. *Bottom.* External carotid angiography in same patient demonstrating meningeal hypervasculation.







F g 5 Falx tentorial men ngioma with fill ng of veins in early a ter al phase



F g 6 *Top v ews* Ve y early fill ng of ve ns in a p t ent with a ba al nening oma *Lower views* Same p ti nt Recurr nc afte operat on At h stolog cal exam nation there were still no s gns of mal gnancy



Fig 3 A malignant glioma in the parietal temporal region has infiltrated the dura and receives part of its blood supply *from the external* carotid artery a) Internal carotid angiography b) External carotid angiography Arrows point at the draining veins



Fig 4 *Top left* Internal carotid angiography in a patient with parietal parasagittal glioma adherent to the dura *Bottom* External carotid angiography in same patient demonstrating meningeal hypervasculation





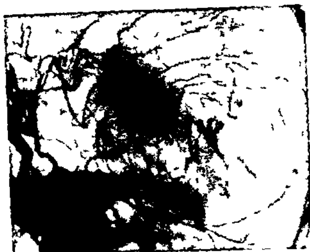
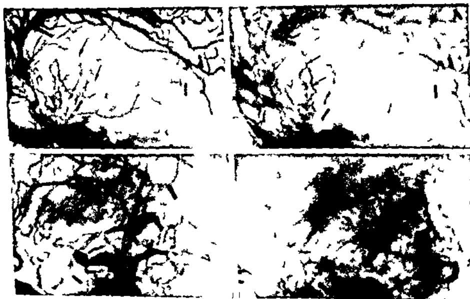


Fig 5 Falx tentorial meningioma with fill ng of veins in early arterial phase



F g 6 *T p t ews* V y ea ly filling of veins in a pat ent with a basal men ngioma *Lowe t ws* Sa n pat nt Recur ence after operation At hi tological examinat on ther were still no s gns of mal gnancy



Fig. 3. A malignant glioma in the parietal temporal region has infiltrated the dura and receives part of its blood supply from the external carotid artery. a) Internal carotid angiography. b) External carotid angiography. Arrows point at the draining veins.



Fig. 4. *Top left.* Internal carotid angiography in a patient with parietal parasagittal glioma adherent to the dura. *Bottom.* External carotid angiography in same patient demonstrating meningeal hypervasculation.







Fig 5 Falx tentorial meningioma with filling of veins in early arterial phase

Fig 6 *Top view* Very early filling of veins in a patient with a basal meningioma *Lower views* Same patient Recurrence after operation At histological examination there were still no signs of malignancy



Fig 3 A malignant glioma in the parietal temporal region has infiltrated the dura and receives part of its blood supply from the external carotid artery a) Internal carotid angiography b) External carotid angiography Arrows point at the draining veins



Fig 4 *Top left* Internal carotid angiography in a patient with parietal parasagittal glioma adherent to the dura *Bottom* External carotid angiography in same patient demonstrating meningeal hypervasculation







Fig 7 Electronic subtraction pictures from an external carotid angiography series on a convexity meningioma. Small arteries are still filled and the tumor is stained with contrast medium. Arrows point at contrast already visible in a wide venous groove.

pathologists that these dura infiltrating gliomas on invasion frequently change their histological character to become more meningiomatous. Examples of gliomas supplied by meningeal vessels are shown in Figs 3 and 4.

According to most authors it is typical for meningiomas to have a long tumor circulation time with late filling of tumor veins. This criterion, although often reliable, does not always in our experience hold true. In approximately 170 intracranial meningiomas examined by angiography the tumor circulation time was found to be rather short in a number of cases. In 10 cases, veins within or on the surface of the tumor or veins draining the tumor, started to fill at approximately the same time as other intracranial veins. In 16 cases, tumor veins started to fill towards the end of the arterial filling phase before other veins were visible, and in 8 cases tumor veins filled at the beginning of the arterial filling phase, indicating arteriovenous shunts. Such very early filling of the veins may present diagnostic difficulty, especially if tumor vessels are atypical and characteristic vascular displacement is not evident. Examples of early venous filling are shown in Figs 5 and 6.

Wide venous grooves and diploic channels of the skull are a common finding in certain intracranial meningiomas. At angiography performed with ordinary technique it is hardly possible to observe contrast filling in these venous pathways. In studies with subtraction technique it has been possible in some

instances to demonstrate fairly early appearance of contrast in venous grooves (Fig 7) and it is possible that the appearance of slow circulation through meningiomas may, at least in some cases be more deceptive than real It is probable that introduction of more dense contrast media and further refinement of the technique including the use of subtraction methods will make it possible also to demonstrate contrast filling in venous grooves of the skull and other draining path ways in a greater number of cases

SUMMARY

It has been found in angiographic studies that the meningeal vascular supply and the tumor circulation time are not always reliable criteria for the differentiation of meningiomas from other intracranial expanding lesions

ZUSAMMENFASSUNG

Mittels angiographischen Studien wurde festgestellt dass die Meningealgefasszufuhr und die Zirkulationszeit im Tumor nicht immer zuverlassliche Kriterien fur die Differention der Meningiomen von anderen intrakranialen Tumoren sind

RÉSUMÉ

Des études angiographiques ont montré que l existence d un apport vasculaire meningé et le temps de circulation dans la tumeur ne sont pas toujours des criteres fidèles pour distinguer les meningiomes d autres tumeurs intracraniennes

REFERENCES

1 GREITZ T A radiologic study of the brain circulation by rapid serial angiography of the carotid artery Acta radiol Suppl 140 1956
2 MILETTI M Die differentialdiagnose der Gehirngeschwulste durch die Arteriographie Acta neurochir Suppl 1 1950
3 SCHIEFER W TONNIS W und LOVARHELYI G Die Art des Meningeoms im Gefassbild Dtsch Z Nervenheilk 173 (1955) 436
4 WICKBOM I Angiographic determination of tumour pathology Acta radiol 40 (1953) 529
5 WICKBOM I and STATTIN S Roentgen examination of intracranial meningiomas Acta radiol 50 (1958) 175



Fig. 7. Electronic subtraction pictures from an external carotid angiography series on a convexity meningioma. Small arteries are still filled and the tumor is stained with contrast medium. Arrows point at contrast already visible in a wide venous groove.

pathologists that these dura infiltrating gliomas on invasion frequently change their histological character to become more meningiomatous. Examples of gliomas supplied by meningeal vessels are shown in Figs 3 and 4.

According to most authors it is typical for meningiomas to have a long tumor circulation time with late filling of tumor veins. This criterium, although often reliable, does not always in our experience hold true. In approximately 170 intracranial meningiomas examined by angiography the tumor circulation time was found to be rather short in a number of cases. In 10 cases, veins within or on the surface of the tumor or veins draining the tumor, started to fill at approximately the same time as other intracranial veins. In 16 cases, tumor veins started to fill towards the end of the arterial filling phase before other veins were visible, and in 8 cases tumor veins filled at the beginning of the arterial filling phase indicating arteriovenous shunts. Such very early filling of the veins may present diagnostic difficulty, especially if tumor vessels are atypical and characteristic vascular displacement is not evident. Examples of early venous filling are shown in Figs 5 and 6.

Wide venous grooves and diploic channels of the skull are a common finding in certain intracranial meningiomas. At angiography performed with ordinary technique it is hardly possible to observe contrast filling in these venous pathways. In studies with subtraction technique it has been possible in some

instances to demonstrate fairly early appearance of contrast in venous grooves (Fig 7) and it is possible that the appearance of slow circulation through meningiomas may, at least in some cases be more deceptive than real It is probable that introduction of more dense contrast media and further refinement of the technique including the use of subtraction methods will make it possible also to demonstrate contrast filling in venous grooves of the skull and other draining path ways in a greater number of cases

SUMMARY

It has been found in angiographic studies that the meningeal vascular supply and the tumor circulation time are not always reliable criteria for the differentiation of meningiomas from *other intracranial expanding lesions*

ZUSAMMENFASSUNG

Mittels angiographischen Studien wurde festgestellt dass die Meningealgefässzufuhr und die Zirkulationszeit im Tumor nicht immer zuverlässliche Kriterien fur die Differention der Meningiomen von anderen intrakranialen Tumoren sind

RÉSUMÉ

Des etudes angiographiques ont montré que l existence d un apport vasculaire méningé et le temps de circulation dans la tumeur *ne sont pas toujours des criteres fidèles pour distinguer* les meningiomes d autres tumeurs intracraniennes

REFERENCES

1 GREITZ T A radiologic study *of the brain circulation by rapid serial angiography of the* carotid artery Acta radiol Suppl 140 1956

2 MILETTI M Die differentialdiagnose der Gehirngeschwulste durch die Arteriographie Acta *neurochir Suppl 1 1950*

3 SCHIEFER W TONNIS W und LDVARHELYI G Die Art des *Meningeoms im Gefassbild* Dtsch Z Nervenheilk 172 (1955) 436

4 WICKBOM I Angiographic determination of tumour pathology Acta radiol 40 (1953) 529

5 WICKBOM I and STATTIN S Roentgen examination of intracranial meningiomas Acta radiol 50 (1958) 175



Fig 7 Electronic subtraction pictures from an external carotid angiography series on a convexity meningioma Small arteries are still filled and the tumor is stained with contrast medium Arrows point at contrast already visible in a wide venous groove

pathologists that these dura infiltrating gliomas on invasion frequently change their histological character to become more meningiomatous Examples of gliomas supplied by meningeal vessels are shown in Figs 3 and 4

According to most authors it is typical for meningiomas to have a long tumor circulation time with late filling of tumor veins This criterium, although often reliable, does not always in our experience hold true In approximately 170 intracranial meningiomas examined by angiography the tumor circulation time was found to be rather short in a number of cases In 10 cases veins within or on the surface of the tumor or veins draining the tumor, started to fill at approximately the same time as other intracranial veins In 16 cases, tumor veins started to fill towards the end of the arterial filling phase before other veins were visible, and in 8 cases tumor veins filled at the beginning of the arterial filling phase, indicating arteriovenous shunts Such very early filling of the veins may present diagnostic difficulty, especially if tumor vessels are atypical and characteristic vascular displacement is not evident Examples of early venous filling are shown in Figs 5 and 6

Wide venous grooves and diploic channels of the skull are a common finding in certain intracranial meningiomas At angiography performed with ordinary technique it is hardly possible to observe contrast filling in these venous pathways In studies with subtraction technique it has been possible in some

instances to demonstrate fairly early appearance of contrast in venous grooves (Fig 7) and it is possible that the appearance of slow circulation through meningiomas may at least in some cases be more deceptive than real It is probable that introduction of more dense contrast media and further refinement of the technique including the use of subtraction methods will make it possible also to demonstrate contrast filling in venous grooves of the skull and other draining path ways in a greater number of cases

SUMMARY

It has been found in angiographic studies that the meningeal vascular supply and the tumor circulation time are not always reliable criteria for the differentiation of meningiomas from other intracranial expanding lesions

ZUSAMMENFASSUNG

Mittels angiographischen Studien wurde festgestellt dass die Meningealgefässzufuhr und die Zirkulationszeit im Tumor nicht immer zuverlassliche Kriterien fur die Differention der Meningiomen von anderen intrakranialen Tumoren sind

RÉSUMÉ

Des etudes angiographiques ont montré que l existence d un apport vasculaire meninge et le temps de circulation dans la tumeur ne sont pas toujours des critères fidèles pour distinguer les mén ngiomes d autres tumeurs intracraniennes

REFERENCES

1 GREITZ T A radiologic study of the brain circulation by rapid serial angiography of the carotid artery Acta radiol Suppl 140 1956
2 MILETTI M Die differentialdiagnose der Gehirngeschwulste durch die Arteriographie Acta neurochir Suppl 1 1950
3 SCHIEFER W TONNIS W und UDVARHELYI G Die Art des Meningeoms im Gefassbild Dtsch Z Nervenheilk 172 (1955) 436
4 WICKBOM I Angiographic determination of tumour pathology Acta radiol 40 (1953) 529
5 WICKBOM I and STATTIN S Roentgen examination of intracranial meningiomas Acta radiol 50 (1958) 175



Fig 7. Electronic subtraction pictures from an external carotid angiography series on a convexity meningioma. Small arteries are still filled and the tumor is stained with contrast medium. Arrows point at contrast already visible in a wide venous groove.

pathologists that these dura infiltrating gliomas on invasion frequently change their histological character to become more meningiomatous. Examples of gliomas supplied by meningeal vessels are shown in Figs 3 and 4.

According to most authors it is typical for meningiomas to have a long tumor circulation time with late filling of tumor veins. This criterium, although often reliable, does not always in our experience hold true. In approximately 170 intracranial meningiomas examined by angiography the tumor circulation time was found to be rather short in a number of cases. In 10 cases, veins within or on the surface of the tumor or veins draining the tumor, started to fill at approximately the same time as other intracranial veins. In 16 cases, tumor veins started to fill towards the end of the arterial filling phase *before* other veins were visible, and in 8 cases tumor veins filled at the beginning of the arterial filling phase, indicating arteriovenous shunts. Such very early filling of the veins may present diagnostic difficulty, especially if tumor vessels are atypical and characteristic vascular displacement is not evident. Examples of early venous filling are shown in Figs 5 and 6.

Wide venous grooves and diploic channels of the skull are a common finding in certain intracranial meningiomas. At angiography performed with ordinary technique it is hardly possible to observe contrast filling in these venous pathways. In studies with subtraction technique it has been possible in some

instances to demonstrate fairly early appearance of contrast in venous grooves (Fig 7) and it is possible that the appearance of slow circulation through meningiomas may at least in some cases, be more deceptive than real It is probable that introduction of more dense contrast media and further refinement of the technique including the use of subtraction methods will make it possible also to demonstrate contrast filling in venous grooves of the skull and other draining path ways in a greater number of cases

SUMMARY

It has been found in angiographic studies that the meningeal vascular supply and the tumor circulation time are not always reliable criteria for the differentiation of meningiomas from other intracranial expanding lesions

ZUSAMMENFASSUNG

Mittels angiographischen Studien wurde festgestellt dass die Meningealgefasszufuhr und die Zirkulationszeit im Tumor nicht immer zuverlassliche Kriterien fur die Differention der Meningiomen von anderen intrakranialen Tumoren sind

RÉSUMÉ

Des etudes angiographiques ont montré que l existence d un apport vasculaire méningé et le temps de circulation dans la tumeur ne sont pas toujours des criteres fideles pour distinguer les méningiomes d *autres tumeurs intracraniennes*

REFERENCES

1 Creitz T A radiologic study of the brain circulation by rapid serial angiography of the carotid artery Acta radiol Suppl 140 1956

2 Miletti M Die differentialdiagnose der Gehirngeschwulste durch die Arteriographie Acta neurochir Suppl 1 1950

3 Schiefer W Tonnis W und Udvarhelyi G Die Art des *Meningeoms im Gefassbild* Dtsch Z Nervenheilk 172 (1955) 436

4 Wickbom I Angiographic determination *of tumour pathology* Acta radiol 40 (1953) 529

5 Wickbom I and Stattin S *Roentgen* examination of intracranial meningiomas Acta radiol 50 (1958) 175



Fig 7 Electronic subtraction pictures from an external carotid angiography series on a convexity meningioma Small arteries are still filled and the tumor is stained with contrast medium Arrows point at contrast already visible in a wide venous groove

pathologists that these dura infiltrating gliomas on invasion frequently change their histological character to become more meningiomatous Examples of gliomas supplied by meningeal vessels are shown in Figs 3 and 4

According to most authors it is typical for meningiomas to have a long tumor circulation time with late filling of tumor veins This criterium, although often reliable, does not always in our experience hold true In approximately 170 intracranial meningiomas examined by angiography the tumor circulation time was found to be rather short in a number of cases In 10 cases, veins within or on the surface of the tumor or veins draining the tumor, started to fill at approximately the same time as other intracranial veins In 16 cases, tumor veins started to fill towards the end of the arterial filling phase before other veins were visible, and in 8 cases tumor veins filled at the beginning of the arterial filling phase indicating arteriovenous shunts Such very early filling of the veins may present diagnostic difficulty, especially if tumor vessels are atypical and characteristic vascular displacement is not evident Examples of early venous filling are shown in Figs 5 and 6

Wide venous grooves and diploic channels of the skull are a common finding in certain intracranial meningiomas At angiography performed with ordinary technique it is hardly possible to observe contrast filling in these venous pathways In studies with subtraction technique it has been possible in some

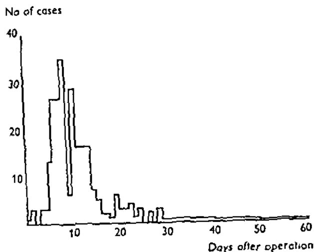


Fig 1 Block diagram showing interval between operation and angiography in 250 cases

ing to their site Aneurysms at (or near) the origin of the posterior communicating artery (86 cases) were placed in group 1 Group 2 (61 cases) consists of aneurysms at (or near) the anterior communicating artery and group 3 (56 cases) of aneurysms on the middle cerebral artery The cases in group 4 (29 cases) include 16 cases of aneurysm at the internal carotid bifurcation (8 left 8 right) 10 cases of aneurysm arising from one of the pericallosal arteries and one case each of aneurysm of the basilar artery left vertebral artery and right carotid artery near the origin of the ophthalmic artery Multiple aneurysms comprising group 5 (18 cases) are cases in which more than one aneurysm was treated otherwise cases of multiple aneurysm are grouped as single aneurysm according to the site of the treated aneurysm One of the cases in group 5 was a female patient aged 49 who had a saccular aneurysm of the right posterior inferior cerebellar artery and a small arteriovenous malformation on the upper surface of the right cerebellar hemisphere both lesions were successfully dealt with at one operation and this case has been reported elsewhere (FINE et coll 1960) Apart from this case and one other of middle cerebral aneurysm with supratentorial vascular malformation also dealt with at one operation all the cases in group 5 are of multiple saccular aneurysms In one of these cases three aneurysms were dealt with, although one was incompletely occluded In the others two aneurysms were treated and in two of these cases one of the aneurysms was incompletely occluded

FROM THE DEPARTMENT OF RADIOLOGY, WEST OF SCOTLAND NEUROSURGICA
UNIT, KILLEARN HOSPITAL, GLASGOW, SCOTLAND

POSTOPERATIVE ANGIOGRAPHY IN TREATMENT OF INTRACRANIAL ANEURYSMS

by

J. LESLIE STEVEN

Surgical treatment of intracranial aneurysms is in many cases directed towards obliteration of the sac, but as ALLCOCK & DRAKE (1963) have pointed out, there is a scarcity of information regarding the efficacy of procedures designed to do this. As these authors observe, it is simple enough to check on the immediate results by postoperative angiography, and they reported on the findings in 70 cases in which this had been done.

The present paper deals with a further 250 cases subjected to angiography after operative treatment over a five year period from 1959 to 1963. Not in every case operated on was a postoperative angiography performed, some succumbed soon after operation before angiography could be carried out, and a few have been omitted because of incomplete documentation.

The material consists of 165 female patients and 85 male patients ranging in age from 15 to 68 years. The average age of male patients was 40 and of female patients 45. Although female patients outnumbered males by 2 to 1 this ratio was not constant in all groups, thus of aneurysms of the anterior communicating artery operated upon 33 were females, 29 males, and in the group of aneurysms of the posterior communicating artery females outnumbered males by 3 to 1.

The aneurysms in the 250 cases were distributed in five main groups accord

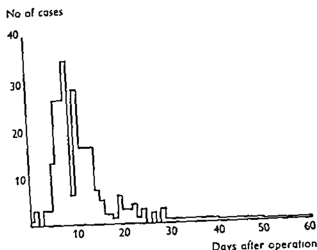


Fig 1 Block diagram showing interval between operation and angiography in 250 cases

ing to their site Aneurysms at (or near) the origin of the posterior communicating artery (86 cases) were placed in group 1 Group 2 (61 cases) consists of aneurysms at (or near) the anterior communicating artery and group 3 (56 cases) of aneurysms on the middle cerebral artery The cases in group 4 (29 cases) include 16 cases of aneurysm at the internal carotid bifurcation (8 left 8 right) 10 cases of aneurysm arising from one of the pericallosal arteries and one case each of aneurysm of the basilar artery left vertebral artery and right carotid artery near the origin of the ophthalmic artery Multiple aneurysms comprising group 5 (18 cases) are cases in which more than one aneurysm was treated otherwise cases of multiple aneurysm are grouped as single aneurysm according to the site of the treated aneurysm One of the cases in group 5 was a female patient aged 49 who had a saccular aneurysm of the right posterior inferior cerebellar artery and a small arterio venous malformation on the upper surface of the right cerebellar hemisphere both lesions were successfully dealt with at one operation and this case has been reported elsewhere (FINE et coll 1960) Apart from this case and one other of middle cerebral aneurysm with supratentorial vascular malformation also dealt with at one operation all the cases in group 5 are of multiple saccular aneurysms In one of these cases three aneurysms were dealt with although one was incompletely occluded In the others two aneurysms were treated, and in two of these cases one of the aneurysms was incompletely occluded

FROM THE DEPARTMENT OF RADIOLOGY, WEST OF SCOTLAND NEUROSURGICAL UNIT, KILLEARN HOSPITAL, GLASGOW, SCOTLAND

POSTOPERATIVE ANGIOGRAPHY IN TREATMENT OF INTRACRANIAL ANEURYSMS

by

J. LESLIE STEVEN

Surgical treatment of intracranial aneurysms is in many cases directed towards obliteration of the sac, but as ALLCOCK & DRAKE (1963) have pointed out, there is a scarcity of information regarding the efficacy of procedures designed to do this. As these authors observe, it is simple enough to check on the immediate results by postoperative angiography and they reported on the findings in 70 cases in which this had been done.

The present paper deals with a further 250 cases subjected to angiography after operative treatment over a five year period from 1959 to 1963. Not in every case operated on was a postoperative angiography performed: some succumbed soon after operation before angiography could be carried out, and a few have been omitted because of incomplete documentation.

The material consists of 165 female patients and 85 male patients ranging in age from 15 to 68 years. The average age of male patients was 40 and of female patients 45. Although female patients outnumbered males by 2 to 1 this ratio was not constant in all groups, thus of aneurysms of the anterior communicating artery operated upon 33 were females, 29 males, and in the group of aneurysms of the posterior communicating artery females outnumbered males by 3 to 1.

The aneurysms in the 250 cases were distributed in five main groups accord

Table 1

Incidence of incomplete occlusion of aneurysms

Site	Totals	Incompletely occluded	
Posterior communicating	86	13	15
Anterior communicating	61	17	28
Middle cerebral	56	7	12 5
Bifurcation of internal carotid	16	3	18 7
Pericallosal	10	0	—
Others	3	1	—
Multiple	18	3	—

although 41 (67 %) of the cases of aneurysm of the anterior communicating artery were subjected to bilateral carotid angiography postoperatively The interval between operation and the first postoperative angiography varied from a few hours to 2 months but in 191 cases (75 %) the examination was performed within 14 days of operation The average interval was 10 days (Fig 1)

Surgical treatment In most cases haematoma or clot if present, was aspirated and the neck of the aneurysm was clipped with small Olivecrona clips occasionally large Olivecrona or Mayfield clips were used In 30 cases clipping was supplemented by silk ligature packing with muscle graft or wrapping with gauze Six aneurysms were ligated without clips in one case after clipping had failed in one of these cases however the ligature slipped off and the neck of the aneurysm was eventually clipped at a later operation In a very few cases of aneurysm of the anterior communicating artery trapping between clips was performed or the sac was obliterated with several clips In the process of occluding anterior communicating aneurysms and to a lesser extent middle cerebral and other aneurysms major arteries or branches were sometimes deliberately or inadvertently occluded (see below) In 5 cases of posterior communicating aneurysms and 1 case of carotid siphon aneurysm the internal carotid artery itself was permanently occluded intracranially with clips during attempts to occlude the aneurysm as the only way to control bleeding Thirteen of the cases of multiple aneurysm were treated at one operation

Incidence of incomplete occlusion of aneurysms An aneurysm was classified as incompletely occluded if the fundus or any part of the fundus was outlined at the postoperative angiography CRAWFORD (1959) has shown that probably

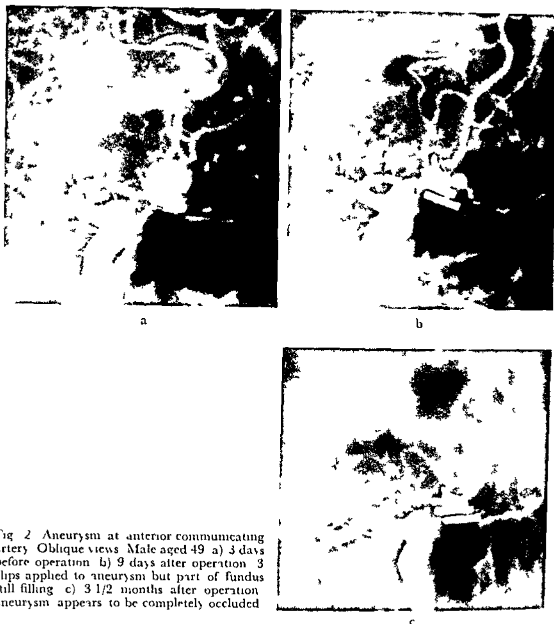


Fig 2 Aneurysm at anterior communicating artery Oblique views Male aged 49 a) 3 days before operation b) 9 days after operation 3 clips applied to aneurysm but part of fundus still filling c) 3 1/2 months after operation aneurysm appears to be completely occluded

Technique and procedure

With few exceptions angiography was performed under general anaesthesia The preoperative angiographic examination consisted of bilateral carotid angiographies (unilateral in a few cases where third nerve palsy had been the main presenting symptom) followed, usually at a later session, by unilateral or bilateral vertebral angiographies in 39 cases (15 6 %) The postoperative angiography was in general unilateral and confined to the side of the aneurysm,

Table 1

Incidence of incomplete occlusion of aneurysms

Site	Totals	Incompletely occluded	
Posterior communicating	86	13	15
Anterior communicating	61	17	28
Middle cerebral	56	7	12 5
Bifurcation of internal carotid	16	3	18 7
Pericallosal	10	0	—
Others	3	1	—
Multiple	18	3	—

although 41 (67 %) of the cases of aneurysm of the anterior communicating artery were subjected to bilateral carotid angiography postoperatively The interval between operation and the first postoperative angiography varied from a few hours to 2 months but in 191 cases (75 %) the examination was performed within 14 days of operation The average interval was 10 days (Fig 1)

Surgical treatment In most cases haematoma or clot if present was aspirated and the neck of the aneurysm was clipped with small Olivecrona clips occasionally large Olivecrona or Mayfield clips were used In 30 cases clipping was supplemented by silk ligature packing with muscle graft or wrapping with gauze Six aneurysms were ligated without clips, in one case after clipping had failed in one of these cases however the ligature slipped off and the neck of the aneurysm was eventually clipped at a later operation In a very few cases of aneurysm of the anterior communicating artery trapping between clips was performed or the sac was obliterated with several clips In the process of occluding anterior communicating aneurysms and to a lesser extent middle cerebral and other aneurysms major arteries or branches were sometimes deliberately or inadvertently occluded (see below) In 5 cases of posterior communicating aneurysms and 1 case of carotid siphon aneurysm the internal carotid artery itself was permanently occluded intracranially with clips during attempts to occlude the aneurysm as the only way to control bleeding Thirteen of the cases of multiple aneurysm were treated at one operation

Incidence of incomplete occlusion of aneurysms An aneurysm was classified as incompletely occluded if the fundus or any part of the fundus was outlined at the postoperative angiography CRAWFORD (1959) has shown that probably

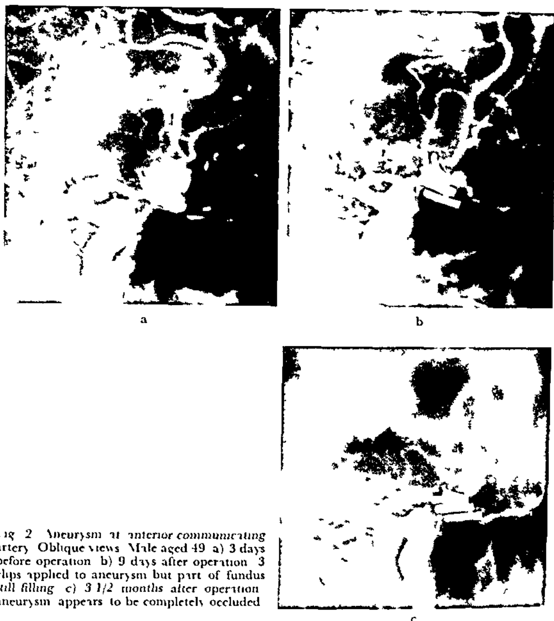


Fig 2 Aneurysm at anterior communicating artery Oblique views Male aged 49 a) 3 days before operation b) 9 days after operation 3 clips applied to aneurysm but part of fundus *still filling* c) *3 1/2 months after operation* aneurysm appears to be completely occluded

Technique and procedure

With few exceptions angiography was performed under general anaesthesia The preoperative angiographic examination consisted of bilateral carotid angiographies (*unilateral in a few cases where third nerve palsy had been the* main presenting symptom) followed, usually at a later session by unilateral or bilateral vertebral angiographies in 39 cases (15 6 %) The postoperative angiography was in general unilateral and confined to the side of the aneurysm

would seem that the technical problems of occluding the sac are greatest with aneurysms in the neighbourhood of the anterior communicating artery

Late follow up angiographies (from 3 1/2 months to 4 years) were performed in 11 cases affording an opportunity to study the situation at the site of the original operation In two cases (anterior communicating artery, Fig 2 left carotid bifurcation Fig 7) aneurysms which had been only partly occluded at the immediate postoperative angiography were shown at the later angio graphies (3 1/2 and 4 months postoperatively) to be completely occluded These cases were nevertheless classified as being incompletely occluded because it was the immediate effect of the technique of occlusion which it was desired to assess it is possible that in these patients, re bleeding could have occurred from the remnant before occlusion became complete

In a further case of incomplete occlusion (anterior communicating aneurysm) there was no apparent change 4 months postoperatively in another (left middle cerebral aneurysm) some enlargement of the remaining portion of the sac was evident at 5 months postoperatively and complete occlusion was eventually secured at a second operation (Fig 3)

In the remaining 7 cases the aneurysms which had been shown to be com pletely occluded at the immediate postoperative angiography showed no recurrence in angiographies performed at periods of 6 months (2 cases, posterior communicating), 8 months (posterior communicating) 1 year (middle cerebral) 1 year and 3 months (anterior communicating) 1 year and 6 months (posterior communicating) and 4 years (middle cerebral) However in one of these cases which had been re examined by carotid and vertebral angiography because of recurrence of subarachnoid haemorrhage although no further aneurysm was found there appeared to be some dilatation of the carotid artery at the site of the previously clipped aneurysm (Fig 4) Re exploration showed no evidence of bleeding in this area In one case a part of the neck was outlined at the first postoperative angiography and no change was evident at the later angio graphy (Fig 5)

Postoperative clinical complications It is generally assumed that occlusion or spasm of a major artery or its branches may cause ischaemic damage to the part of the brain supplied by the affected vessel as both these appearances were found to be common after intracranial operations on aneurysms an attempt was made to correlate the angiographic appearances with the patient s postoperative clinical state at the time of the check angiography Some difficulty was experienced in classifying clinical states but it was decided for the purposes of this study to divide the cases into those which showed no postoperative deterioration and those which did, such deterioration was assess

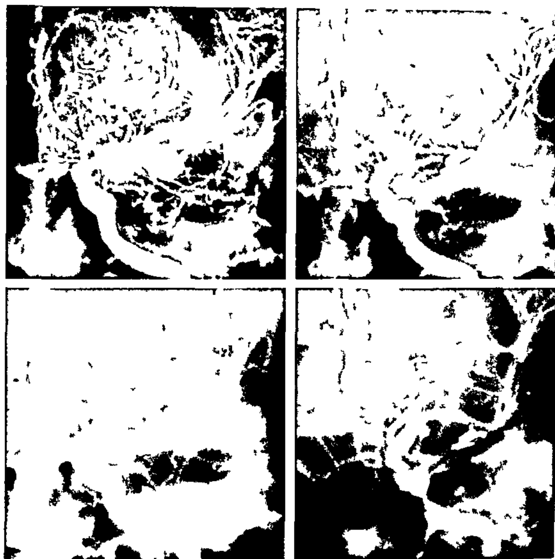


Fig 3 Aneurysm of left middle cerebral artery A p views Female aged 49 *Top left* 2 days before operation *Top right* 9 days after operation clip on neck aneurysm not occluded but reduced in size *Lower left* 5 months after operation aneurysm has increased in size *Lower right* 12 days after the angiogram at lower left and 7 days after second operation further clip applied aneurysm completely occluded

only 2 or 3 % of aneurysms bleed from the neck and in this study therefore an aneurysm was regarded as successfully occluded even when the neck proximal to the clip was outlined postoperatively On this basis, incomplete occlusion was found in 44 cases of the series an overall incidence of 17 6 %, which corresponds closely with the figure of 18 5 % found by ALLCOCK & DRAKE in their series Table 1 shows the incidence of incomplete occlusion in the main sites While an aneurysm at any site presents its own difficulties it

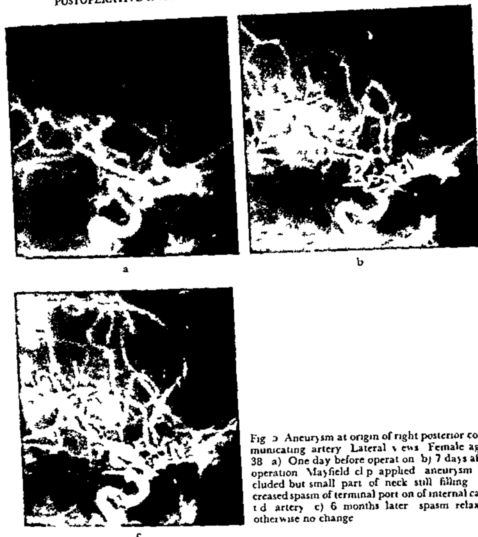


Fig 5 Aneurysm at origin of right posterior communicating artery Lateral views Female aged 38 a) One day before operation b) 7 days after operation Mayfield clip applied aneurysm occluded but small part of neck still filling Increased spasm of terminal portion of internal carotid artery c) 6 months later spasm relaxed otherwise no change

one or both anterior cerebral arteries and as such studies were performed in only 67 % of cases of aneurysm of the anterior communicating artery a few cases of postoperative vascular occlusion were possibly not discovered There was evidence of occlusion of a main artery or one or more of its major branches in 60 cases of the series an incidence of 24 % In 40 cases the surgeon had either deliberately occluded the vessel or was aware that he might have occluded a major branch In 23 cases one of the pericallosal arteries was occluded, and in 5 cases both these arteries were occluded In 9 cases one middle cerebral

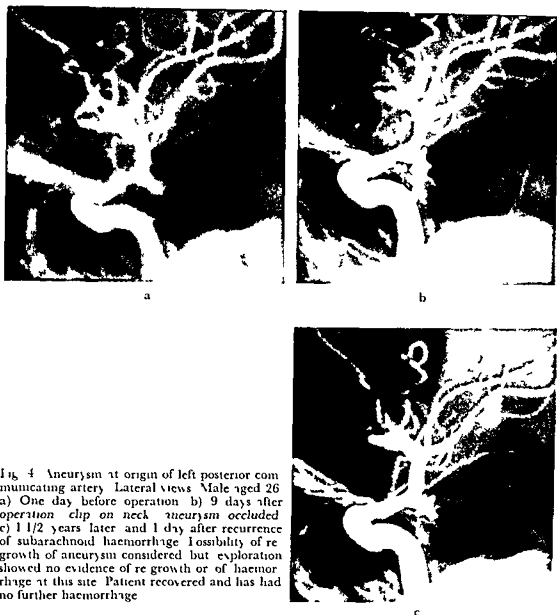


Fig 4 Aneurysm at origin of left posterior communicating artery Lateral views Male aged 26 a) One day before operation b) 9 days after *operation clip on neck aneurysm occluded* c) 1 1/2 years later and 1 day after recurrence of subarachnoid haemorrhage Possibility of regrowth of aneurysm considered but exploration showed no evidence of regrowth or of haemorrhage at this site Patient recovered and has had no further haemorrhage

ed by the development or exacerbation since operation of neurological signs, eg, hemiparesis, hemiplegia, and dysphasia, and signs of mental upset eg, confusion and akinetic mutism In a great many considerable improvement or complete recovery occurred in the period following the postoperative angiography, but this was not taken into account

Vascular occlusion Without cross compression studies and, if necessary, bilateral angiography, it may not be possible to demonstrate unequivocal occlusion of

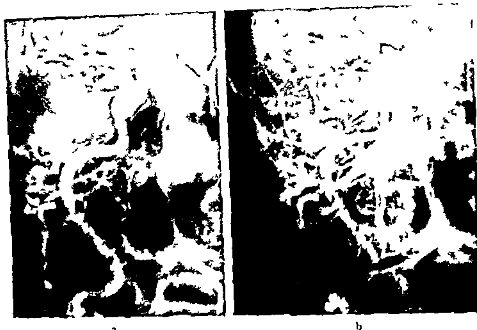


Fig 6 Aneurysm at orig n of right poster or communicating artery A-p iews Female aged 44 a) 2 days bef re ope ation b) 31 days after operat on 4 cl ps occluding internal carotid artery cons derable eduction of lumen of proximal part of artery

formly reduced to half or less the preoperative diameter (Fig 6) and the phenomenon is presumably associated with the considerably reduced flow

Spasm The series offered an opportunity to study the incidence of spasm as with two or more angiographies separated by an interval of several days even small alterations in vessel calibre could be easily detected Of the 191 cases which had their first check angiography within 14 days after operation 114 (59 7 %) showed new or increased spasm 24 cases (12 5 %) showed some degree of relaxation and in 31 cases (16 2 %) there was considered to be no spasm either before or after operation

The presence of spasm was clearly related to the interval since operation, the earlier the angiography the more commonly was spasm found and the more severe it was Thus in every one of 10 cases in which angiographies were performed within 5 days of operation new or increased spasm was noted severe or extensive in six In all 16 cases considered to have severe postoperative spasm the angiographies were performed within 11 days of operation (Fig 7) There was a reduction in the incidence of new or increased spasm from 100 %

Table 2

Relationship of postoperative vascular occlusion to patient's postoperative condition (3 main groups)

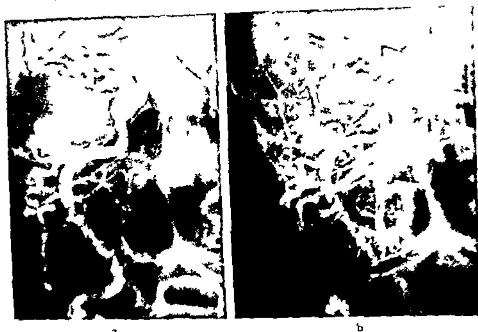
Site	Totals	Cases with postoperative vascular occlusion	
		Clinical deterioration	No deterioration
Posterior communicating	86	5 (5.8 %)*	1 (1.2 %)
Anterior communicating	61	11 (18 %)	9 (14.7 %)
Middle cerebral	56	13 (23.2 %)	9 (16 %)

* Includes one case of occlusion of middle cerebral artery

artery, and, in 16 cases, one or more branches of this artery were occluded. In 7 cases an internal carotid artery was occluded — in 6 deliberately (as noted above) and in 1 probably as a consequence of clipping the middle cerebral artery near its origin in a case of aneurysm in the region of the carotid bifurcation, where, after a clip had been applied to its neck, the aneurysm tore off the parent vessel.

Of the 60 cases showing vascular occlusion, 34 (56.6 %) had evidence of clinical deterioration and in the remaining 190 cases in which no definite vascular occlusion could be detected 71 (37.3 %) had evidence of deterioration. Table 2 shows the relationship of postoperative vascular occlusion to the patient's postoperative state in the three commonest aneurysmal sites.

These findings suggest that deterioration with vascular occlusion is not related to the aneurysm which is treated but to the vessel occluded, the high incidence of deterioration in the posterior communicating group reflects the tendency for vascular occlusion, when it occurs with aneurysms at this site, to affect the internal carotid artery itself. While there is obviously a greater risk of deterioration with vascular occlusion in general, the relationship is not consistent and one may infer that other lesions may be responsible for deterioration, in cases with and without evidence of occlusion. Even the presence of collateral circulation may not prevent the occurrence of signs of vascular deficiency. For example, of the 7 cases of internal carotid occlusion, 4 showed severe neurological deficit postoperatively in spite of collateral circulation having been demonstrated angiographically, preoperatively in two, and postoperatively in the other two. In the 6 cases where the internal carotid artery had been clipped there was reduced calibre of the internal carotid artery from its origin to the level of occlusion at the siphon. The lumen of the vessel was uni



F g 6 Aneurysm at origin of right posterior communicating artery A p views Female aged 54 a) 2 days before operation b) 31 days after operat on 4 cl ps occluding internal carotid artery cons derable reduction of lumen of proximal part of artery

formly reduced to half or less the preoperative diameter (Fig 6) and the phenomenon is presumably associated with the considerably reduced flow

Spasm The series offered an opportunity to study the incidence of spasm as with two or more angiographies separated by an interval of several days even small alterations in vessel calibre could be easily detected Of the 191 cases which had their first check angiography within 14 days after operation 114 (59 7 %) showed new or increased spasm 24 cases (12 5 %) showed some degree of relaxation and in 31 cases (16 2 %) there was considered to be no spasm either before or after operation

The presence of spasm was clearly related to the interval since operation the earlier the angiography the more commonly was spasm found and the more severe it was Thus in every one of 10 cases in which angiographies were per formed within 5 days of operation new or increased spasm was noted, severe or extensive in six In all 16 cases considered to have severe postoperative spasm the angiographies were performed within 11 days of operation (Fig 7) There was a reduction in the incidence of new or increased spasm from 100 %

Table 2

Relationship of postoperative vascular occlusion to patient's postoperative condition (3 main groups)

Site	Totals	Cases with postoperative vascular occlusion	
		Clinical deterioration	No deterioration
Posterior communicating	86	5 (5 8 %)*	1 (1 2 %)
Anterior communicating	61	11 (18 %)	9 (14 7 %)
Middle cerebral	56	13 (23 2 %)	9 (16 %)

* Includes one case of occlusion of middle cerebral artery

artery, and, in 16 cases, one or more branches of this artery were occluded In 7 cases an internal carotid artery was occluded — in 6 deliberately (as noted above) and in 1 probably as a consequence of clipping the middle cerebral artery near its origin in a case of aneurysm in the region of the carotid bifurcation, where, after a clip had been applied to its neck, the aneurysm tore off the parent vessel

Of the 60 cases showing vascular occlusion, 34 (56 6 %) had evidence of clinical deterioration and in the remaining 190 cases in which no definite vascular occlusion could be detected 71 (37 3 %) had evidence of deterioration Table 2 shows the relationship of postoperative vascular occlusion to the patient s postoperative state in the three commonest aneurysmal sites

These findings suggest that deterioration with vascular occlusion is not related to the aneurysm which is treated but to the vessel occluded, the high incidence of deterioration in the posterior communicating group reflects the tendency for vascular occlusion, when it occurs with aneurysms at *this site*, to affect the internal carotid artery itself While there is obviously a greater risk of deterioration with vascular occlusion in general, the relationship is not consistent and one may infer that other lesions may be responsible for deterioration, in cases with and without evidence of occlusion Even the presence of collateral circulation may not prevent the occurrence of signs of vascular deficiency For example, of the 7 cases of internal carotid occlusion, 4 *showed* severe neurological deficit postoperatively in spite of collateral circulation having been demonstrated angiographically, preoperatively in *two*, and postoperatively in the other *two* *In the 6 cases where the internal* carotid artery had been clipped there was reduced calibre of the internal carotid artery from its origin to the level of occlusion at the siphon The lumen of the vessel was uni

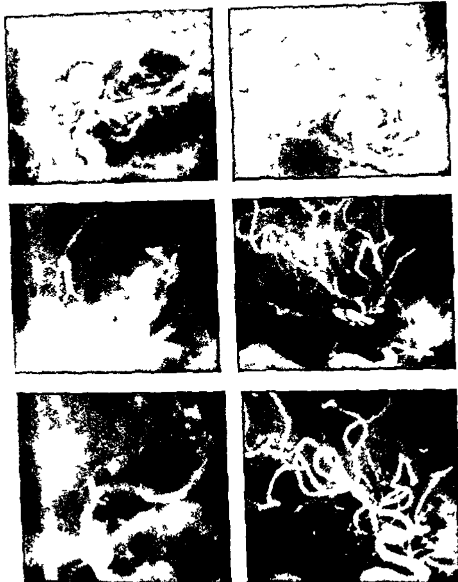


Fig 7 Large aneurysm at bifurcation of left internal carotid artery A p films on left lateral films on right *Upper views* 6 days before operation *Centre views* 9 days after operation aneurysm not completely occluded severe spasm *Patient well no* neurological signs *Lower views* 4 months after operation aneurysm completely occluded relaxation of spasm Left anterior cerebral artery may be occluded

Table 3

Relationship of postoperative spasm to patient's postoperative condition

Site	Cases with increased spasm*		No increase of spasm*	
	With deterioration	Without deterioration	With deterioration	Without deterioration
Posterior communicating	12 (14 %)	32 (37 %)	10 (11.6 %)	26 (30.[illegible] %)
Anterior communicating	14 (22.9 %)	9 (14.7 %)	8 (13.1 %)	10 (16.4 %)
Middle cerebral	5 (8.9 %)	11 (20 %)	6 (10.7 %)	12 (21.4 %)

* Excluding cases with vascular occlusion

in the first 5 post operative days to 61 % of 105 angiographies from 6 to 10 days after operation, 50 % of 83 angiographies from 11 to 15 days, and 43 % of 30 angiographies from 16 to 25 days after operation These findings suggest that operation in cases of subarachnoid haemorrhage provokes or aggravates spasm DU BOULAY (1963), however, considered that there was no direct evidence that generalised spasm was provoked or prolonged by operation, but in the 24 cases in his series it appears that the average interval between operation and check angiography was 17 days as against 10 days in the present series, and this difference may explain the apparently contradictory conclusions

Excluding cases with evidence of vascular occlusion there were 104 cases showing new or increased spasm postoperatively, in 41 of these (39.4 %) there was clinical deterioration Similarly, of 86 cases showing no fresh spasm after operation, 31 (36.0 %) had clinical deterioration Table 3 compares the incidence of deterioration with spasm in aneurysms at the three main sites Only with anterior communicating aneurysms was there any correlation between increased spasm and clinical deterioration and then it was not very striking In the 16 cases with severe spasm there were 7 which showed definite deterioration but in the remainder there was either improvement or no deterioration On the other hand, of the 24 cases in which there was some relaxation of spasm, 11 cases (46 %) showed varying degrees of deterioration (although in 4 of these there was also evidence of vascular occlusion) Of the 31 cases considered to have no spasm before or after operation 5 cases (16 %) showed some deterioration (vascular occlusion in one case) It seems reasonable to conclude from these findings that although operation may aggravate or provoke spasm in cases of subarachnoid haemorrhage, such spasm does not appear to have such damaging effects as are generally attributed to the spasm of spontaneous preoperative haemorrhage

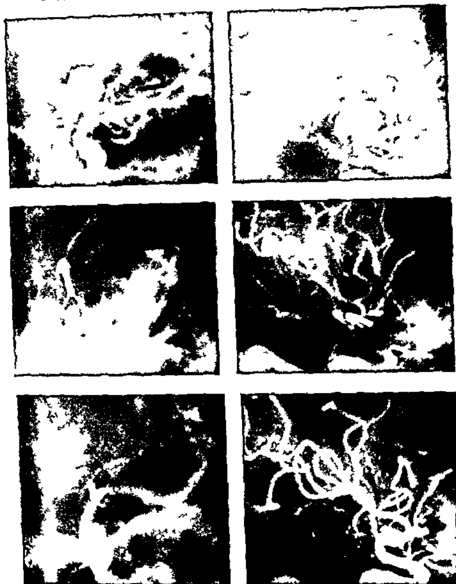


Fig 7 Large aneurysm at bifurcation of left inte nal ca otid artery A p films on left lateral films on r ght *Uppe views* 6 days b fore op at on *Centre views* 9 days after operat on aneurysm not complet ly oc luded severe spasm P tient well no neurolog cal s gns *Lo er vi w* 4 m nths *after ope* at on aneurysm compl tely occluded relaxation of spasm Left a ter or cerebral art ry may be occluded

Acknowledgements

I wish to thank my surgical colleagues, J Sloan Robertson J Schorstein A Paterson and W B Jennett for giving me access to the records of their patients and for advice and encouragement

SUMMARY

A *series of 250* cases of intracranial aneurysms treated by operative occlusion have been studied with postoperative angiography to elucidate the incidence of incomplete occlusion of the aneurysms as well as postoperative vascular occlusion and spasm An attempt has been made to assess the extent to which these latter complications may affect the patient s post operative clinical condition

ZUSAMMENFASSUNG

Eine Serie von 250 Fällen von intracraniellen Aneurysmen die operativ verschlossen worden waren wurden angiographisch untersucht um das Vorkommen von inkompletten Verschluss wie auch postoperativem Verschluss und Spasmus zu untersuchen

RÉSUMÉ

Pour déterminer la fréquence de l occlusion chirurgicale incomplete des anévrismes de l occlusion vasculaire post opératoire et du spasme l auteur a examiné par angiographie post opératoire une série de 250 cas d anévrismes intracraniens traités par occlusion chirurgical Il a essayé de déterminer dans quelle mesure ces complications peuvent influer sur l état clinique post opératoire du malade

REFERENCES

ALLCOCK J M and DRAKE C G Post operative angiography in cases of ruptured intracranial aneurysm J Neurosurg 20 (1963) 752

DU BOULAY G Distribution of spasm in the intracranial arteries after subarachnoid haemorrhage Acta radiol 1 (1963) 257

CRAWFORD T Symposium on intracranial aneurysms — pathological aspects Brit J Radiol 32 (1959) 84

FINE R PATERSON A STEVEN J L and GAYLOR J B Simultaneous occurrence of intracranial aneurysm and arterio venous malformation Brit Med J 2 (1960) 711

FROM ST VINCENT S HOSPITAL OF THE CITY OF NEW YORK U S A

COMPARISON OF POSTOPERATIVE ANGIOGRAPHIC APPEARANCE AND CLINICAL SIGNS IN ARTERIAL ANEURYSM OF THE INTRACAVERNOUS INTERNAL CAROTID ARTERY

by

LAWRENCE STRENGER

According to JEFFERSON (13) the first complete clinical picture of a non fistulous intracavernous carotid aneurysm was described by BARTHOLOW (4) in 1872 In 1869 ADAMS (1) published A case of aneurysm of the internal carotid artery in the cavernous sinus causing paralysis of the third fourth fifth and sixth nerves Many (5 7 8 10 13 20) since then have written of the syndrome of the lateral wall of the cavernous sinus

Certain radiological signs have been frequently seen with intracavernous aneurysms and are considered by some to be classical (2) The earliest ap preciated (5 12 19) changes were adventitious calcifications (as Albl s rings) later the significance of associated erosive phenomenon was appreciated (2 15 16 17 18) LOMBARDI and his associates (15) recently summarized the changes noted in their series

Although it may not be true in all cases (15 17) angiography generally offers the sine qua non in the establishment of the diagnosis of an intracavernous aneurysm It is frequently used to illustrate the response of the lesion to

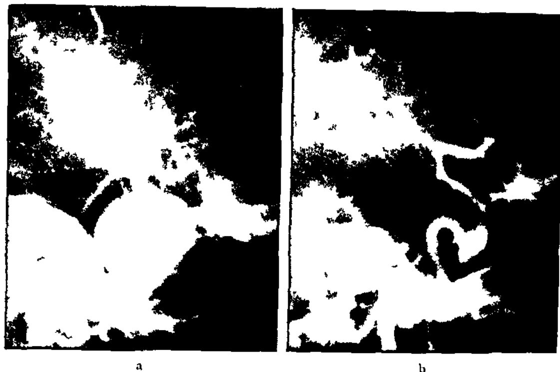


Fig 1 Case 1 Angiograms taken before operation (a) and afterwards (b)

therapy The following cases demonstrate the failure of correlation between the postoperative angiographic appearance of the aneurysm and the clinical signs

Case reports

Case 1 A 54 year old Spanish speaking housewife from Puerto Rico was admitted to St Vincent s Hospital complaining of progressive diplopia of six months duration She demonstrated a left lateral rectus paresis a ptotic left eyelid with anisocoria (the left pupil being larger than the right) Routine studies including cerebrospinal fluid examination were unremarkable A large saccular aneurysm of the intracavernous portion of the left internal carotid artery was demonstrated by angiography (Fig 1 a) Adequate cross filling was suggested by the cross compression studies and was confirmed by the Matas Test Three days later a left common carotid ligation was performed On examination the next morning a total left ophthalmoplegia was in evidence The pupil was dilated and fixed and the lid completely ptosed The second day she complained of severe left sided head pain which persisted

On the 13th postoperative day a left carotid angiography was performed (Fig 1 b) This demonstrated minimal filling at the site of the sac with the patient in the supine position In order to obviate chances of failure of filling of the aneurysm because of the layering effect additional films were taken with the patient in the prone position The ophthalmoplegia and left frontal pain persisted until the time of discharge 6 weeks after the operation



Fig 2 Case 2 Angiograms taken before operation (a) and afterwards (b)

Case 2 A 55-year old West Indian Negress was admitted to St Vincent s Hospital complaining of right retro-orbital pain of two weeks duration This began suddenly and was of progressive severity Further inquiry elicited that her right eye began turning in approximately three years prior to the time of her admission

Examination revealed an obese anxious hypertensive negress with a blood pressure of 210/120 mm Hg She demonstrated loss of visual acuity of the right eye (a right superior nasal quadrant defect on visual field examination) pallor of the right optic disc and a depressed right corneal reflex There was also a right lateral rectus palsy The routine skull films were suggestive of the presence of an infraclinoid aneurysm This was confirmed by angiography (Fig 2 a) A series of films taken with cross compression suggested the adequacy of cross circulation and was supported by the Matas Test Common carotid ligation was performed The patient refused postoperative angiography at this admission

Approximately three weeks later she returned to the hospital complaining of severe right retro orbital pain The right eye was now totally amblyopic and additional extraocular palsies were noted Angiography at this time revealed non filling of the aneurysmal sac (Fig 2 b) The pain abated after three months but she did not recover vision or any significant extraocular movements

Case 3 A 44 year old American white female was investigated for headache at Jefferson Medical College in 1962 A carotid angiography was performed on the right side revealing a small infraclinoid aneurysm Subsequently a right common carotid ligation was performed There was remission of the head pain but it returned a few weeks later with increased severity She presented herself approximately two years later complaining of syncopal episodes and right frontal head pain Examination revealed hypesthesia over the ophthalmic division of the right trigeminus and a mild paresis of the right medial rectus muscle She was admitted to the Shore Memorial Hospital and a right carotid angiography was performed 18 months after the first investigation No aneurysm or other intracranial mass was identified

Discussion

DANDY (6) and HAMBY (11) felt that orbital pain was highly suggestive of enlargement of the intracavernous aneurysms. The cases presented demonstrate that collapse or thrombosis of the sac, as demonstrated angiographically, may lead to the same complaint. The associated ocular and extra ocular muscle signs may also be aggravated. Others (9, 14) have reported similar situations.

In these cases the mechanics of production of the signs is obscure. The collapsing sac may have caused traction upon the dura of the lateral wall of the cavernous sinus affecting the adjacent structures. The wall of the lateral sinus is innervated by the nervus meningus medius arising principally from the trigeminus. The implications of pain referral are obvious. However, the fact that the aneurysmal sac does not fill with contrast medium at postoperative angiography does not necessarily mean it has reduced at all in size. The entire sac may be filled with thrombus. This might suggest that ischemia of the area is being produced by involvement of the small vessels arising from the intra cavernous carotid artery, as described by PARKINSON. This explanation seems less tenable than the former considering the available anastomosis, and the apparent patency of adjacent vessels. The pathophysiology is, as stated, enigmatic.

SUMMARY

Three cases of intracavernous arterial carotid aneurysms treated by common carotid ligation are presented and the failure of correlation between angiographically demonstrated resolution of the lesions and improvement in clinical signs is discussed.

ZUSAMMENFASSUNG

Drei Fälle von intrakavernosem Carotisaneurysma wurde mit Carotisligatur behandelt. Die Diskrepanz zwischen angiographischem Befund und dem Verlauf der klinischen Symptome wird besprochen.

RÉSUMÉ

L'auteur présente trois cas d'anévrisme carotidien intracaverneux traités par ligature de la carotide primitive. Il étudie la discordance entre la disparition de la lésion prouvée par l'angiographie et les signes cliniques.

REFERENCES

1. ADAMS, J. Aneurysms of the internal carotid in the cavernous sinus. Lancet 2 (1869) 768.
2. ALAJOUANINE, T., THUREL, R., NEHLIL, J. et BALDACCI, Y. L'anevrysme du siphon carotidien et son retentissement osseux (Reunion du trou optique et de fente sphenoidale). Rev. neurol. 92 (1955) 249.

3 ALBL H Aneurysma der Carotis Interna einen Hypophysentumor vortauschen Ein Beitag zur Diagnose Intrakraniellen Aneurysmen Fortschr Rontgenstr 39 (1939) 890

4 BARTHOLOW R Aneurysms of the arteries at the base of the brain Their symptomatology diagnosis and treatment Amer J med Sci 64 (1872) 373

5 DANDY W E Intra cranial arterial aneurysms in the carotid canal Diagnosis and treatment A M A Arch Surg 45 (1942) 335

6 — Intra cranial arterial aneurysms Comstock Publishing Co Ithaca N Y 1944

7 DAVIS L E Lesions of the paratrigeminal area J Amer med Ass 80 (1923) 380

8 — and MARTIN J Surgical lesions of the paratrigeminal area J Amer med Ass 113 (1939 1592

9 FISHER R G and GORAN A Thrombosis of an intracranial aneurysm and cervical portion of the internal carotid artery in a child J Neurosurg 18 (1961) 698

10 FOIX C Syndrome de la paroi externe du sinus caverneus Rev neurol 38 (1922) 827

11 HAMBY W B Intracranial aneurysms Charles C Thomas Springfield Ill 1952

12 HEUER G J and DANDY W E Roentgenography in the localization of brain tumors based upon a series of one hundred consecutive cases Bull Johns Hopk Hosp 27 (1916) 311

13 JEFFERSON G On the saccular aneurysms of the internal carotid in the cavernous sinus Brit J Surg 26 (1938) 267

14 LEVITT J M Aneurysm of the internal carotid artery simulating tumor Report of a case Arch Ophthal 43 (1950) 500

15 LOMBARDI G PASSERINI A and MIGLIAVACCA F Intracavernous aneurysms of the internal carotid artery Amer J Roentgenol 88 (1963) 361

16 MCKINNEY J ACREE T and STOLTZ S Syndrome of the unruptured aneurysm of intracranial portion of internal carotid artery Bull Neurol Inst 5 (1936) 247

17 MEADOWS S P Intracavernous aneurysms of the internal carotid artery Their clinical features and natural history Arch Ophthal 62 (1959) 566

18 RISCHBIETH R H C and BULL J W D Significance of enlargement of superior orbital (sphenoid) fissure Brit J Radiol 31 (1958) 125

19 SOSMAN M C and VOGT E C Aneurysms of the internal carotid artery and the Circle of Willis from a roentgenological viewpoint Amer J Roentgenol 15 (1926) 122

20 STOPFORD J S B The arteries of the pons and medulla oblongata III J Anat 51 (1917) 250

Discussion

DANDY (6) and HAMBY (11) felt that orbital pain was highly suggestive of enlargement of the intracavernous aneurysms. The cases presented demonstrate that collapse or thrombosis of the sac, as demonstrated angiographically, may lead to the same complaint. The associated ocular and extra ocular muscle signs may also be aggravated. Others (9, 14) have reported similar situations.

In these cases the mechanics of production of the signs is obscure. The collapsing sac may have caused traction upon the dura of the lateral wall of the cavernous sinus affecting the adjacent structures. The wall of the lateral sinus is innervated by the nervus meningeus medius arising principally from the trigeminus. The implications of pain referral are obvious. However, the fact that the aneurysmal sac does not fill with contrast medium at postoperative angiography does not necessarily mean it has reduced at all in size. The entire sac may be filled with thrombus. This might suggest that ischemia of the area is being produced by involvement of the small vessels arising from the intracavernous carotid artery, as described by PARKINSON. This explanation seems less tenable than the former considering the available anastomosis, and the apparent patency of adjacent vessels. The pathophysiology is, as stated, enigmatic.

SUMMARY

Three cases of intracavernous arterial carotid aneurysms treated by common carotid ligation are presented and the failure of correlation between angiographically demonstrated resolution of the lesions and improvement in clinical signs is discussed.

ZUSAMMENFASSUNG

Drei Fälle von intrakavernosem Carotisaneurysma wurde mit Carotisligatur behandelt. Die Diskrepanz zwischen angiographischem Befund und dem Verlauf der klinischen Symptome wird besprochen.

RÉSUMÉ

L'auteur présente trois cas d'anévrisme carotidien intracaverneux traités par ligature de la carotide primitive; il étudie la discordance entre la disparition de la lésion prouvée par l'angiographie et les signes cliniques.

REFERENCES

1. ADAMS J. Aneurysms of the internal carotid in the cavernous sinus. Lancet 2 (1869) 768.
2. ALAJOUANINE T., THUREL R., NEHLIL J. et BALDACCI Y. L'aneurysme du siphon carotidien et son retentissement osseux (Reunion du trou optique et de fente sphenoidale). Rev. neurol. 92 (1955) 249.



Fig 1 Angiogram showing slightly angioblastic meningioma of the olfactory groove with typical meningioma arrangement of the vessels (group II) without obvious irregularities It cannot be differentiated from a benignant meningioma



Fig 2 Angiography A slightly angioblastic meningioma arising from the anterior clinoid process Wheel spoke arrangement of the tumour vessels as in a benignant meningioma but also slight irregularities of the same vessels (lumen variations small pathologic connections) suggesting the presence of angioblastic growth (group II)

Serafimerlasarettet in Stockholm All cases are histologically verified most of them by one and the same experienced pathologist

In the angiographies performed before 1952 only slow series were used from 1952 to 1955 both slow and rapid series and ever since 1955 only rapid series which in this material means 10 films at a rate of two films per second immediately followed by 10 films at a rate of one film per second

The material available consists of 46 cases which I have subdivided into the following four groups on the basis of the angiographic appearance of the tumour vessels group I tumours angiographically poor in vessels (9 cases approx 20 %) group II tumour vessels with typical meningioma arrangement (10 cases 20 %) group III tumours moderately rich in irregular vessels (16 cases 35 %) group IV tumours very rich in irregular vessels (11 cases 25 %) In no case was the angiographic appearance normal

In *group I* dislocation of vessels outside the tumour could be seen in the angiograms while the tumour itself appeared poor in vessels In the remaining three groups at least one feeding artery was always a branch from the external carotid artery which means that for all practical purposes the diagnosis of a

FROM THE ROENTGEN DEPARTMENT (DIRECTOR: PROF. ERIK LINDGREN) OF SERAFIMERLASARETTET, STOCKHOLM, SWEDEN

ANGIOGRAPHIC APPEARANCE OF ANGIOBLASTIC MENINGIOMAS

by

RUNE TELENIUS

In a meningioma the tumour vessels are lined either by endothelial cells or directly by tumour cells. In the latter case the histologic structure is said to be angioblastic. If at least some part of a meningioma is found to have such an angioblastic structure the meningioma is classified as angioblastic, even if most of the tumour vessels are lined by ordinary endothelium. This definition of an angioblastic meningioma is the one used in this paper (cf. BERGSTRAND & OLIVECRONA 1935, CUSHING & EISENHARDT 1938, O. T. BAILEY 1940, P. BAILEY 1948, ZULCH 1956).

As is well known the angioblastic meningiomas have a bad prognosis compared to ordinary meningiomas (cf. BERGSTRAND & OLIVECRONA, CUSHING & EISENHARDT), and as a rule the more widespread the angioblastic way of growth in the tumour, the more difficult is the operation and the worse is the prognosis. It is therefore of definite value to be able to diagnose a meningioma as angioblastic before the operation, and also if possible to determine the extent of the angioblastic growth.

The present investigation consists of a study of carotid and vertebral angiographies of cases of angioblastic meningiomas operated upon since 1951 at



Fig 5 Angiogram of large recurrence of a highly angioblastic convexity meningioma The angiogram shows strikingly all types of irregularities of the tumour vessels (pathologic vessels of malignancy) but without rapid passage from feeding arteries to drainage veins The circulation time through the tumour was the same as outside the tumour No capillary blush

meningioma (not necessarily angioblastic) was definite in about 80 % of the whole material

Group II (cf MONIZ 1940 LORENZ 1940 WICKBOM 1948 1953 WICKBOM & STATTIN 1958 LIMA 1950 MILLETTI 1950 LINDGREN 1954, SCHIEFER & TONNIS 1954 SCHIEFER et coll 1955) will be illustrated by two typical cases

Fig 1 shows an angioblastic meningioma of the olfactory groove where the feeding meningial branches enter the center of the tumour and the cerebral feeding arteries the periphery without any irregularity of the tumour vessels It cannot be differentiated from an ordinary non angioblastic meningioma (in fact it was only slightly angioblastic)

Fig 2 represents an angioblastic meningioma of the anterior clinoid process with the typical wheel spoke arrangement of the tumour vessels But in this case there are slight irregularities with lumen variations of the tumour vessels and pathologic connections between them giving rise to small irregular sinuses in the tumour suggesting that this is not an entirely ordinary meningioma but an angioblastic one

In *group III* the irregularities of the tumour vessels are more apparent

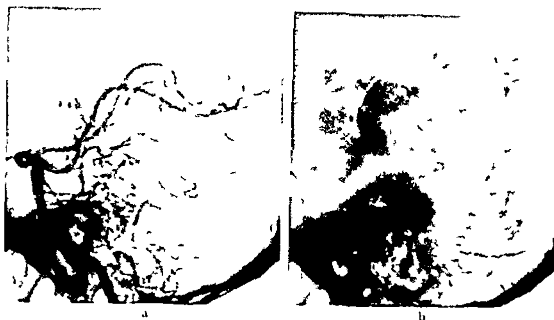


Fig 3 Angiography a) A moderately angioblastic meningioma infiltrating the tentorium (group III) The irregularity of some of the vessels is more apparent than in group II b) Irregular capillary blush



Fig 4 Angiogram showing a highly angioblastic meningioma of the posterior fossa The tumour vessels are very tortuous and very irregular in details with lumen variations and pathologic connections (group IV) (Later on the contrast medium passed over into a longstanding capillary blush No arteriovenous shunting through the tumour)

Table

Correlation between histologic and angiographic findings

Histologic group (1—4)	Angiographic group (I—IV)			
	I	II	III	IV
1 Extensive regressive changes	6	1	2	= 9
2 Slightly angioblastic	3	6	2	= 11
3 Moderately angioblastic		2	11	4 = 17
4 Highly angioblastic		1	1	7 = 9
	9	10	16	11 = 46

30 cases i e about 65 % of the whole material had a longstanding capillary blush with prolonged circulation time The absence of rapid arterio venous shunts is of course valuable for the differential diagnosis between angioblastic meningiomas and other malignant intracranial lesions (For a more detailed discussion see HEMMINGSSON 1939, ENGESET 1944 WICKBOM 1948, 1953, MILLETTI 1950 SCHIEFER, TONNIS & UDVARHELYI 1954 1955 GREITZ 1956 BERNASCONI & CASSINARI 1958 ZACHRISSON 1963 STATTIN 1964)

Correlation between histologic and angiographic findings By separating those tumours in which the regressive histologic changes were extensive (histologic group I in the Table) from the rest of the cases and then grading the latter according to the extent of the angioblastic mode of growth into slightly moderately and highly angioblastic meningiomas (histologic groups 2—4 in the Table) it has been possible to correlate four histologic groups with the four above mentioned angiographic groups I—IV The result is shown in the Table As is well seen from this table the correlation between corresponding histologic and angiographic groups 1—I, 2—II 3—III and 4—IV is surprisingly good

Conclusions

1 A positive correlation exists between the histologically found extension of the angioblastic structure in the tumour and the angiographically estimated degree of irregularity of the tumour vessels (irregularity in the sense described above irregular course and arrangement of tumour vessels compared to ordinary meningiomas lumen variations, pathologic connections between vessels within the tumour, often with formation of small sinuses)

2 If the angioblastic meningioma is poor in vessels extensive regressive



Fig 6 Angiograms from the only case in the material where the circulation time was shortened In lower part of tumour there are small irregular vessels in upper part a pathologic connection between two arteries giving rise to an irregular sinus from which the contrast medium successively but not very rapidly passed over into a system of capsular veins (b) and from them to a drainage vein which was filled somewhat earlier than other intracranial veins No capillary blush

Fig 3 shows two films from one and the same angioblastic meningioma infiltrating the tentorium, Fig 3 a shows the moderately irregular feeding arteries and tumour vessels, and Fig 3 b the following capillary blush, more irregular than what is usually the case in an ordinary meningioma

In *group IV* the irregularities of the vessels are striking Fig 4 shows the very *tortuous tumour vessels of a highly angioblastic meningioma in the posterior* fossa Fig 5 is a recurrence of a huge angioblastic convexity meningioma with widespread pathologic connections between the irregular tumour vessels

Fig 6 shows films from the only case (also belonging to group IV) in the entire material where a comparatively rapid passage of contrast medium from arteries to veins could be found Fig 6 a shows a pathologic connection between two arteries within the tumour, and Fig 6 b capsular veins filled earlier than other intracranial veins However, no very rapid passage of the contrast medium directly from a preformed feeding artery into a preformed drainage vein — a useful definition of the so called 'rapid arterio venous shunt — was found in this case or in any other case in the material On the contrary — in spite of the more or less malignant nature of the angioblastic meningiomas — all the other cases in this material had a circulation time (for definition see Greitz 1956) equal to or longer than the rest of the intracranial vessels As many as

REFERENCES

BAILEY O T Histology of meningiomas Arch Path 30 (1940) 42

BAILEY P Intracranial tumours Ch C Thomas Springfield 1948

BERGSTRAND H and OLIVECRONA H Angioblastic meningiomas Amer J Cancer 24 (1935) 522

BERNASCONI V e CASSINARI V Studio angiografico di 207 casi di meningiomi sopratentoriali operati G Psichiat Neuropat 86 (1958) 63

CUSHING and EISENHARDT Meningiomas their classification regional behavior life history and surgical end results Ch C Thomas Springfield and Baltimore 1938

ENGESET A Cerebral angiography with perabrodil Acta radiol Suppl 56 (1944)

GREITZ T A radiologic study of the brain circulation by rapid serial angiography of the carotid artery Acta radiol Suppl 140 (1956) 76 84

HEMMINGSSON H Arteriographic diagnosis of malignant glioma Acta radiol 20 (1939) 499

LIMA P A Cerebral angiography Oxford University Press London 1950

Lindgren E In Handbuch der Neurochir Bd II Springer Berlin 1954 pp 175 179 180

LORENZ R Differentialdiagnose der arteriographisch darstellbaren intracraniellen Geschwülste Glioblastom Meningeom Sarkom Zbl Neurochir I (1940) 30

MILLETTI M Die Differentialdiagnose der Gehirngeschwulste durch die Arteriographie Acta neurochir Suppl 1 (1950)

MONIZ EGAZ Die cerebrale Arteriographie und Phlebographie Handbuch der Neurologie Springer Berlin 1940

SCHIFFER W und TONNIS W Die Bedeutung der Serienangiographie fur die Artdiagnose der Hirngeschwulste Fortschr Rontgenstr 81 (1954) 616

— — und UDVARHELYI G Die Artdiagnose des Meningeoms im Gefasgebild Dtsch Z Nervenheilk 172 (1955) 456

STATTIN S The significance of some angiographic signs of intracranial meningiomas Paper read at the Symp neurorad New York 1964

WICKBOM I Angiography of the carotid artery Acta radiol Suppl LXXII (1948) pp 71 77 78 81

— Angiographic determination of tumour pathology Acta radiol 40 (1953) 529

— and STATTIN S Roentgen examination of intracranial meningioma Acta radiol 50 (1958) 175

ZACHRISSON L Angiography of cerebral metastases Acta radiol Diagn 1 (1963) 521

ZULCH K J In Handbuch der Neurochirurgie Bd 3 Springer Verlag Berlin Gottingen Heidelberg 1956 pp 399 400 411

changes are often found histologically. Consequently the correct diagnosis is difficult. This is the case in about 20 % of the whole material.

3. If the tumour vessels are observed in the angiogram of an angioblastic meningioma, there is also at least one feeding branch from the external carotid artery to give the diagnosis of a meningioma (not necessarily angioblastic). This is true for about 80 % of the whole material, and emphasizes the necessity of a complete angiographic examination of the vessels, preferably separate injections in the external carotid artery, the internal carotid, and the vertebral artery.

4. If the tumour vessels are irregular in the above mentioned meaning, this is a sign of an angioblastic mode of growth, and the correct diagnosis of angioblastic meningioma is possible, in this material in about 70 % of all the cases (groups IV and III and about half of group II).

5. In order to differentiate the angioblastic meningiomas from other more or less malignant intracranial lesions, it is indispensable to study the circulation through the tumour by means of rapid serial angiography (slow series are not enough). A remarkable fact is the complete absence in this material of rapid arterio-venous shunts (as defined above).

SUMMARY

The angiographic appearance of 46 histologically verified angioblastic meningiomas is described and compared with their histologic structure. The differential diagnosis between ordinary (benign) meningiomas and angioblastic meningiomas as well as between angioblastic meningiomas and other malignant intracranial lesions in general is discussed and emphasis is placed on the value of a complete examination of the external carotid, internal carotid and vertebral arteries, and the value of rapid serial angiography is emphasized.

ZUSAMMENFASSUNG

Es wird das Angiogramm von 46 histologisch verifizierten angioblastischen Meningeomen beschrieben und mit ihrer histologischen Struktur verglichen. Es wird die Differenzialdiagnose zwischen den gewöhnlichen (benignen) und angiogblastischen Meningeomen wie auch zwischen angioblastischen Meningeomen und anderen malignen intracraniellen Prozessen allgemein besprochen. Dabei wird auf den Wert einer vollständigen Untersuchung der Art. carotis ext. und int. und der Vertebralarterien hingewiesen, wie auch der Vorteil rascher Serioangiographie hervorgehoben.

RÉSUMÉ

L'auteur décrit l'aspect angiographique de 46 méningiomes angioblastiques vérifiés histologiquement et le compare à leur structure histologique. Il étudie le diagnostic dillérentiel entre les méningiomes ordinaires (bénins) et les méningiomes angioblastiques ainsi qu'entre les méningiomes angioblastiques et les autres lésions intracraniennes malignes en général. Il souligne l'intérêt d'un examen complet des artères carotide externe, carotide interne et vertébrale et l'intérêt de l'angiographie en série rapide.

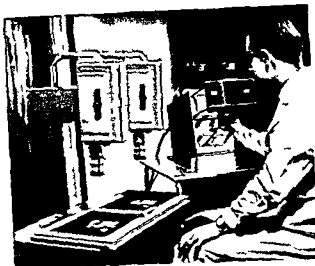


Fig 1 Electronic subtraction equipment To the left are seen the two television camera head and the coordinate table with viewing box for the two films The electronic amplifier units are placed beneath the viewing box Monitor and controls for adjusting brightness contrast and complete registration of the two images are seen to the right The Polaroid camera is tipped down in front of the monitor

or intensity of a single detail or of a few details In its electronic form the difference method (1) is now widely employed in radar for suppressing the stationary background in order to emphasize the radar echoes from moving objects (moving target indication)

If the basic image consists of a conventional roentgenogram and the modification is caused by e g the injection of contrast medium into the blood vessels or a body cavity the method is called subtraction and was presented by ZIEDSES DES PLANTES in his brilliant thesis of 1934

Characteristic for these difference methods is that

a) the modified image is reversed in polarity before it is combined with the basic image

b) the basic image must be stored in some sort of memory before it is combined with the modified image

c) the procedure requires very high accuracy since the processed image consists of the small difference between two closely alike images

d) although no new information is in theory created by the difference process the visibility of the desired details is in certain cases enhanced so considerably that it is in practice permissible to regard the processed image as containing new information

FROM THE DIVISION OF APPLIED ELECTRONICS (DIRECTOR PROF HENRY WALLMAN), CHALMERS UNIVERSITY OF TECHNOLOGY, AND ROENTGEN DEPARTMENT II (DIRECTOR DOCENT I WICKBOM), SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

ELECTRONIC SUBTRACTION

by

HENRY WALLMAN and INGMAR WICKBOM

In the theory of image processing, a family of difference methods has been developed for suppressing unwanted information in an image in order to enhance the visibility of wanted information These difference methods all have the form

Processed image = basic image minus modification of basic image (1)

If the modification consists of defocusing, the method (1) is called 'contrast equalization', or 'harmonization', or the method of the unsharp mask' The purpose is to maintain the visibility of contrast differences in small details while suppressing gross variations of contrast from one large area to another The method is very old in photographic practice, dating from the last century, and was applied to roentgenography by SPIEGLER in 1930 ('Antidurverfahren') The 'Logetron (CRAIG 1954) is an electronic apparatus for achieving harmonization The connection of one of the authors (H W) with image processing arose in 1961 while working on a method for harmonization employing television techniques

The difference method (1) is used in astronomy, in the study of variable stars (1904), for modifications consisting of a small change in the position

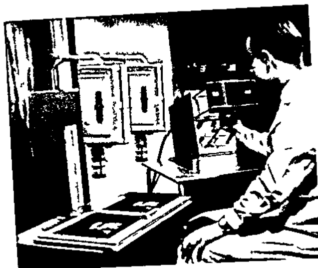


Fig 1 Electronic subtraction equipment To the left are seen the two television camera heads and the coordinate table with viewing box for the two films The electronic amplifier units are placed beneath the viewing box Monitor and controls for adjusting brightness contrast and complete registration of the two images are seen to the right The Polaroid camera is tipped down in front of the monitor

or intensity of a single detail or of a few details In its electronic form the difference method (1) is now widely employed in radar for suppressing the stationary background in order to emphasize the radar echoes from moving objects (moving target indication)

If the basic image consists of a conventional roentgenogram and the modification is caused by e g the injection of contrast medium into the blood vessels or a body cavity the method is called subtraction and was presented by ZIEDSES DES PLANTES in his brilliant thesis of 1934

Characteristic for these difference methods is that

a) the modified image is reversed in polarity before it is combined with the basic image

b) the basic image must be stored in some sort of memory before it is combined with the modified image

c) the procedure requires very high accuracy since the processed image consists of the small difference between two closely alike images

d) although no new information is in theory created by the difference process the visibility of the desired details is in certain cases enhanced so considerably that it is in practice permissible to regard the processed image as containing new information

FROM THE DIVISION OF APPLIED ELECTRONICS (DIRECTOR PROF HENRY WALLMAN), CHALMERS UNIVERSITY OF TECHNOLOGY, AND ROENTGEN DEPARTMENT II (DIRECTOR DOCENT I WICKBOM), SAHLGRENSKA SJUKHUSET, GOTHENBURG, SWEDEN

ELECTRONIC SUBTRACTION

by

HENRY WALLMAN and INGMAR WICKBOM

In the theory of image processing, a family of difference methods has been developed for suppressing unwanted information in an image in order to enhance the visibility of wanted information These difference methods all have the form

Processed image = basic image minus modification of basic image (1)

If the modification consists of defocusing, the method (1) is called 'contrast equalization', or 'harmonization', or 'the method of the unsharp mask' The purpose is to maintain the visibility of contrast differences in small details while suppressing gross variations of contrast from one large area to another The method is very old in photographic practice, dating from the last century and was applied to roentgenography by SPIEGLER in 1930 ('Antidurverfahren') The 'Logetron' (CRAIG 1954) is an electronic apparatus for achieving harmonization The connection of one of the authors (H W) with image processing arose in 1961 while working on a method for harmonization employing television techniques

The difference method (1) is used in astronomy, in the study of variable stars (1904), for modifications consisting of a small change in the position

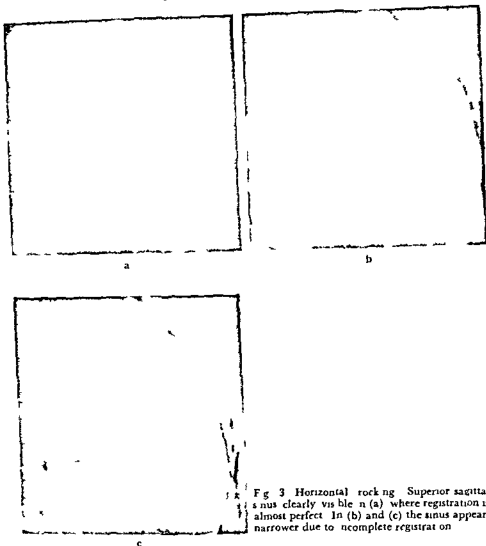


Fig 3 Horizontal rocking Superior sagittal sinus clearly visible in (a) where registration is almost perfect In (b) and (c) the sinus appears narrower due to incomplete registration

vertically above the light box A single synchronizing central contains the sweep generators for the two camera heads and yields a very high level of agreement between the scanning wave forms Special care is devoted to achieving equality of the input output characteristics of the two camera heads and to maintaining high signal to noise ratios The camera heads are provided with matched optical systems with variable focal length Subtraction itself is carried out purely electronically and signal processing after the subtraction

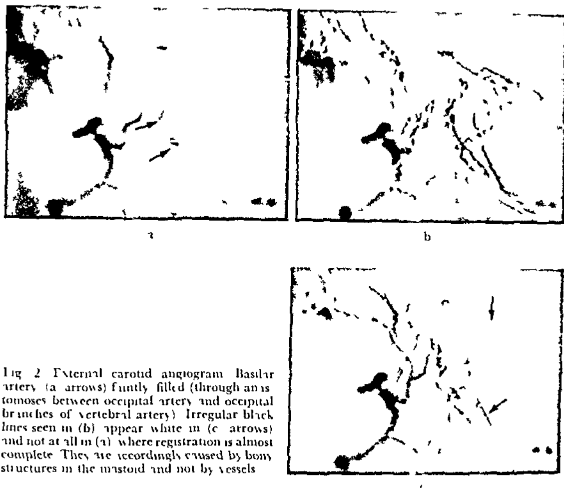


Fig. 2. External carotid angiogram. Basilar artery (a, arrows) faintly filled (through anastomoses between occipital artery and occipital branches of vertebral artery). Irregular black lines seen in (b) appear white in (c, arrows) and not at all in (a) where registration is almost complete. They are accordingly caused by bony structures in the mastoid and not by vessels.

Although these difference methods were all originally devised for photographic methods, the conversion to electronic processing is in each case conceptually simple. Electronic subtraction was proposed and discussed by Ziedses des Plantes in 1961 and Holman in 1963. The degree of success that can be achieved in electronic subtraction is entirely contingent upon the accuracy of execution of the electronic apparatus; without an exceptionally high standard of registration of the two images and very accurate rendition of the grey scale, the results will be disappointing.

The particular apparatus for electronic subtraction described in this contribution (Fig. 1) was designed with special attention to these aspects of accuracy. It was developed at Chalmers University of Technology, Gothenburg, and has been in use since the autumn of 1963.

The two films to be subtracted are placed on a dual light box with coordinate (x- and y-axis) movements and two television camera heads are mounted

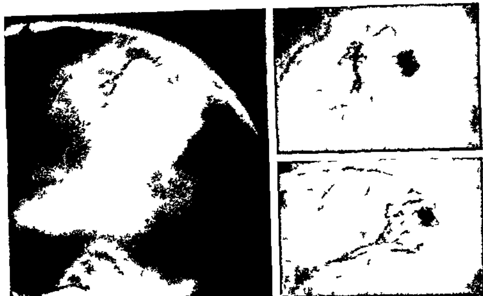


Fig 5 Same case as in fig 4 after injection in external carotid artery (late arterial phase) At top left only one of vascular grooves leading to tumor is visible due to contrast filling of the vein in the other At right electronic subtraction pictures At top right the vein mentioned previously is clearly visible while the other groove is subtracted At centre right where registration is deliberately incomplete the latter is visible as a darker line in upper and a white line in lower part Tumor staining in posterior part of tumor and draining vein in anterior part are best seen at top right At bottom right densities are deliberately unbalanced This case also demonstrates the value of using the subtraction technique when studying the draining veins in meningeomas which in this case are early filled

(Figs 2 to 5) while the film base Polaroid images are a step better in grey scale rendition Neither type of Polaroid material quite reaches the image quality offered by the monitor screen however

In the photographic subtraction process exact registration of the two images requires a certain degree of manual dexterity this is unnecessary with the present equipment where fine adjustment is carried out by moving one of the two images electronically in the horizontal and vertical directions rather than mechanically It is often possible to obtain satisfactory registration in a small area of interest even if the patient has moved slightly between the exposures If as is not frequently the case doubt arises as to whether a dense line in the image on the monitor is caused by a contrast filled vessel or by

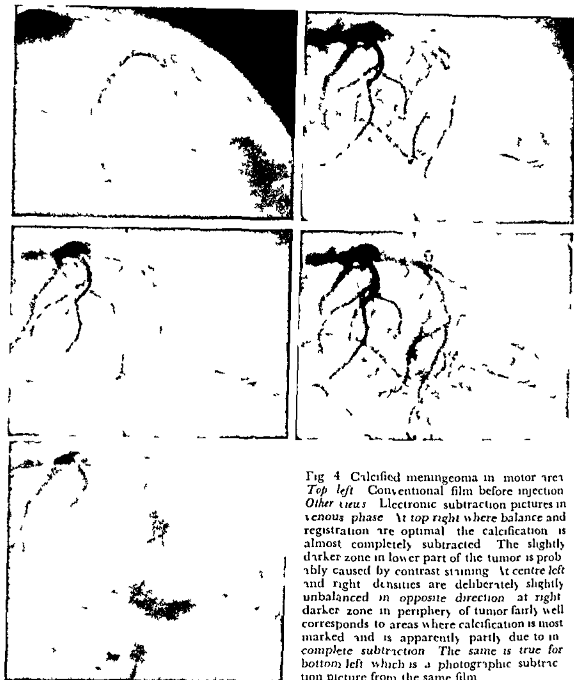


Fig 4 Calcified meningeoma in motor area *Top left* Conventional film before injection *Other views* Electronic subtraction pictures in venous phase *At top right* where balance and registration are optimal the calcification is almost completely subtracted The slightly darker zone in lower part of the tumor is probably caused by contrast staining At centre left and right densities are deliberately slightly unbalanced *in opposite direction* at right darker zone in periphery of tumor fairly well corresponds to areas where calcification is most marked and is apparently partly due to *incomplete subtraction The same is true for* bottom left which is a photographic subtraction picture from the same film

stage is quite uncritical The subtraction image is presented on a television monitor with suitable controls for brightness and contrast

For documentation a Polaroid camera is swung down to photograph the monitor screen Polaroid positive images on paper are available in ten seconds, and on film base in 60 seconds Polaroid paper copies are often adequate

ZUSAMMENFASSUNG

Die Autoren berichten uber ihre Erfahrungen mit einem neuen elektronischen Subtraktionsapparat Die elektronische Methode hat gegenuber dem photographischen Verfahren gewisse Vorteile Die Subtraktionsbilder konnen unmittelbar nach Entwicklung der Filme erhalten werden Das Gleichgewicht die Helligkeit und der Kontrast konnen leicht aufeinander abgestimmt werden ohne dass eine neue Maske erforderlich ist Indem man die beiden Bilder ein wenig hin und herruckt kann auf leichte Weise erkannt werden ob eine dichte Linie oder ein dichter Fleck in Wirklichkeit einer unvollstandig subtrahierten Gefass oder Knochenstruktur entspricht Eine vor dem Bildschirm angebrachte Polaroidkamera erlaubt das Aufnehmen von Bildern zur Archivierung

RESUME

Les auteurs rendent compte de leur experimentation d un nouvel appareil de soustraction electronique La methode electronique présente certains avantages sur la méthode photographique Elle permet d obtenir une image de soustraction immediatement apres le développement du film On peut facilement regler l équilibre la luminosité et le contraste sans avoir à preparer un nouveau masque En faisant bercer un peu les deux images on juge facilement si une ligne ou une tache dense est vraiment une structure vasculaire ou si elle est une structure osseuse incomplètement soustraite Un appareil Polaroid placé devant l ecran permet de prendre des images pour les archives

REFERENCES

HOLMAN C B The application of closed-circuit television in diagnostic radiology Proc Mayo Clin 38 (1964) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol D 2 (1964) 264

ZIEDSES DES PLANTES B G Planigrafie en Subtractie Kemink en Zoon Utrecht 1934

— Subtraktion Thieme Verlag Stuttgart 1961

an incompletely subtracted bony structure, the question can easily be resolved by 'rocking' one of the images slightly in the vertical or horizontal direction A skeletal detail then shows up (Figs 2 and 3) with a white edge first on the one side and then on the other, while a contrast filled vessel is always black (provided of course that a positive monitor image is used) Changing the balance can be used for the same purpose

The use of lenses of variable focal length permits the image to be detail magnified up to four times Brightness and contrast of the subtracted image can be varied electronically to explore a wide range of densities The signal levels from the two images can be adjusted individually to achieve balance by varying the diaphragm of one of the cameras, in this way it is possible to accommodate rather large differences in overall density between the conventional film and the angiogram

Although all these variations can of course also be carried out with the photographic technique, each step would then require a much longer time and often involve processing a new film

The final results of electronic subtraction can not be better than with a perfect photographic subtraction, assuming the best possible photographic balance, contrast, grey scale and registration for the detail in question The advantage of the electronic technique is that all the adjustments mentioned can be carried out very quickly, and by the radiologist himself

Electronics removes subtraction from the photographer and puts it in the hands of the radiologist In practice this is of great importance With the photographic method it is not unusual that a subtraction appears to be optimal but is in fact somewhat incomplete in part of the film (Fig 4, bottom left), which may cause error in the interpretation Such an error can easily be avoided with the electronic method in the manner described above This is illustrated in Figs 4 and 5, which are also intended to give an idea of the quality of the results obtained

SUMMARY

The authors report their experiences with a new apparatus for electronic subtraction The electronic method has certain advantages over the photographic procedure The subtraction picture can be obtained immediately after the films are processed Balance brightness and contrast can be easily adjusted without preparing a new mask By means of rocking the two images it is easily found out whether a dense line or spot is true vascular or a bony structure incompletely subtracted A Polaroid camera can be tipped down in front of the monitor allowing pictures to be taken for archivation

ZUSAMMENFASSUNG

Die Autoren berichten uber ihre Erfahrungen mit einem neuen *elektronischen Subtraktionsapparat* Die elektronische Methode hat gegenuber dem photographischen Verfahren gewisse Vorteile Die Subtraktionsbilder konnen unmittelbar nach Entwicklung der Filme erhalten werden Das Gleichgewicht die Helligkeit und der Kontrast konnen leicht aufeinander abgestimmt werden ohne dass eine neue Maske erforderlich ist Indem man die beiden Bilder ein wenig hin und herruckt kann auf leichte Weise erkannt werden ob eine dichte Linie oder ein dichter Fleck in Wirklichkeit einer unvollstandig subtrahierten Gefass oder *Knochenstruktur entspricht Eine vor dem Bildschirm angebrachte Polaroidkamera erlaubt* das Aufnehmen von Bildern zur Archivierung

RESUMÉ

Les auteurs rendent compte de leur expérimentation d un nouvel appareil de soustraction electronique La méthode electronique présente certains avantages sur la methode photographique Elle permet d obtenir une image de soustraction immédiatement apres le dévelopment du film On peut facilement régler l équilibre la luminosité et le contraste sans avoir à preparer un nouveau masque En faisant bercer un peu les deux images on juge facilement si une ligne ou une tache dense est vraiment une structure vasculaire ou si elle est une structure osseuse incompletement soustraite Un appareil Polaroid placé devant l écran permet de prendre des images pour les archives

REFERENCES

HOLMAN C B The application of closed circuit television in diagnostic radiology Proc Mayo Clin 38 (1964) 67

HORENSTEIN R LUNDH A and SJOGREN S E The subtraction method Acta radiol D 2 (1964) 264

ZIEDSES DES PLANTES B G Planigrafie en Subtractie Kemink en Zoon Utrecht 1934
— *Subtraktion Thieme Verlag Stuttgart 1961*

an incompletely subtracted bony structure, the question can easily be resolved by 'rocking' one of the images slightly in the vertical or horizontal direction. A skeletal detail then shows up (Figs 2 and 3) with a white edge first on the one side and then on the other, while a contrast filled vessel is always black (provided of course that a positive monitor image is used). Changing the balance can be used for the same purpose.

The use of lenses of variable focal length permits the image to be detail magnified up to four times. Brightness and contrast of the subtracted image can be varied electronically to explore a wide range of densities. The signal levels from the two images can be adjusted individually to achieve balance by varying the diaphragm of one of the cameras, in this way it is possible to accommodate rather large differences in overall density between the conventional film and the angiogram.

Although all these variations can of course also be carried out with the photographic technique, each step would then require a much longer time and often involve processing a new film.

The final results of electronic subtraction can not be better than with a perfect photographic subtraction, assuming the best possible photographic balance, contrast, grey scale and registration for the detail in question. The advantage of the electronic technique is that all the adjustments mentioned can be carried out very quickly, and by the radiologist himself.

Electronics removes subtraction from the photographer and puts it in the hands of the radiologist. In practice this is of great importance. With the photographic method it is not unusual that a subtraction appears to be optimal but is in fact somewhat incomplete in part of the film (Fig 4, bottom left), which may cause error in the interpretation. Such an error can easily be avoided with the electronic method in the manner described above. This is illustrated in Figs 4 and 5, which are also intended to give an idea of the quality of the results obtained.

SUMMARY

The authors report their experiences with a new apparatus for electronic subtraction. The electronic method has certain advantages over the photographic procedure. The subtraction picture can be obtained immediately after the films are processed. Balance, brightness and contrast can be easily adjusted without preparing a new mask. By means of rocking the two images it is easily found out whether a dense line or spot is true vascular or a bony structure incompletely subtracted. A Polaroid camera can be tipped down in front of the monitor allowing pictures to be taken for archivation.

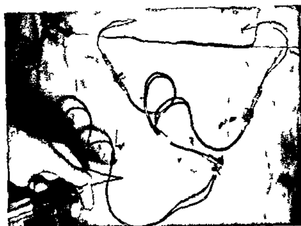


Fig 1 Bilateral percutaneous infraclavicular catheterization of subclavian arteries Catheter of right and left sides connected to the syringe by a Y shaped tube for a bilateral simultaneous injection

Technique The Seldinger technique for arterial catheterization was adapted to the subclavian artery using the infraclavicular approach (FIELDS & WEIBEL 1964 WEIBEL & FIELDS 1963 WEIBEL et coll 1963) General anesthesia was used in 284 patients and local anesthesia in 130 Bilateral subclavian catheterization was carried out in 371 patients and unilateral catheterization in 43 patients Once the polyethylene catheter was placed in the subclavian artery, bilateral *simultaneous* or *unilateral selective injection* of the vertebral arteries was performed with 12 to 15 ml of Conray 60 % being injected in each side (Fig 1)

During the first injection if it was to be unilateral the patient's head and neck were placed in a flat position and turned to the side being injected For a bilateral simultaneous injection the head and neck were turned to the left side Following the first injection the position of the head and neck was changed and other projections appropriate to the patient's symptoms or as suggested by the first film were made The total amount of contrast material injected for a complete study of the vertebrobasilar system varied from 30 to 75 ml for a unilateral injection to 50 to 120 ml for a bilateral study No single injection exceeded 25 ml of contrast material

Results

Bilateral simultaneous or unilateral injection of the subclavian arteries has been found to be a satisfactory means for demonstrating the entire vascular tree of the vertebrobasilar system It readily permits contrast filling of the basilar artery and its branches as obtained by direct injection of the vertebral artery but the technical difficulties and risk of vertebral artery puncture are

FROM THE DEPARTMENT OF NEUROLOGY, BAYLOR UNIVERSITY COLLEGE OF MEDICINE, HOUSTON, TEXAS, U S A

ANGIOGRAPHY OF THE VERTEBROBASILAR ARTERIAL SYSTEM

by

JORGE WEIBEL

Complete demonstration of the vertebrobasilar system has become increasingly important in the diagnosis and determination of proper treatment of lesions involving the cerebral circulation of the posterior fossa Several techniques employed for this purpose include direct vertebral artery puncture, retrograde injection of the right common carotid, direct infraclavicular or supraclavicular puncture of the subclavian, direct puncture or retrograde catheterization of the brachial or axillary arteries, and injection of the innominate and left subclavian arteries by retrograde femoral artery catheterization Unfortunately, these techniques do not readily permit bilateral simultaneous or unilateral selective demonstration of the vertebrobasilar system The purpose of this paper is to report the results of our experience with direct percutaneous infraclavicular catheterization of the subclavian arteries

This technique was used in 414 patients admitted to the hospital with diagnoses of cerebrovascular insufficiency, intracranial aneurysm, arterio venous malformation, and brain tumor Their ages ranged between 11 and 91 years, 285 were male and 129 female



a b

F g 3 a) R ght subcla ian inject on Large normal \e tebral and b silar art ries with fill ng of both poste or c ebral rte es b) Left subcla\ an injection w th he d and neck tu ned to left s de Small left verte bral artery ending n po te ior infer or cerebella artery (rrow)

Fig 4 R ght poster o oblique view fol lo ving inject on of r ght subcla\ ian a tery n order to avo d super mpos t on of common carotid artery (upper arrow) over orig n of vertebral artery (lower ar row) as seen in fig 10a

\ertebral and basilar arteries and their branches \ difference in size between the right and left \ertebral arteries is frequently seen Often a small \ertebral arter\ does not reach the basilar artery but ends in the posterior inferior cerebellar artery (Fig 3) In some cases one \ertebral artery may be absent and the other be of larger caliber Injection of contrast material into the right



a b

Fig 2 a) Bilateral simultaneous injection of subclavian arteries Complete contrast filling of vertebrobasilar system Stenotic lesion and kinking of the left vertebral artery at its origin (arrow) b) Left subclavian injection Very tortuous vertebral artery with moderate stenosis at its origin (lower arrow) reverse flow of contrast material into smaller right vertebral artery (upper arrow) and filling of left posterior cerebral artery (Right posterior cerebral artery filled by right carotid injection)

eliminated (Fig 2) When a unilateral injection is made, the patient's head and neck are turned to the side of the injection since it has been observed that if the head is turned to the side opposite the injection, the vertebral artery may become blocked at the level of the atlanto axial joint When bilateral simultaneous subclavian injection is performed, the head is always turned to the left side because the left vertebral artery is usually larger than the right one and a mechanical block can be avoided on the left side at the level of the atlanto axial joint

By using this method, it is possible for the head and neck to be turned at will, thereby permitting complete demonstration of the entire course of the



a b

Fig 3 a) Right subclavian injection Large normal vertebral and basilar arteries with filling of both posterior cerebral arteries b) Left subclavian injection with head and neck turned to left side Small left vertebral artery ending in posterior inferior cerebellar artery (arrow

Fig 4 Right posterior oblique view following injection of right subclavian artery in order to avoid superimposition of common carotid artery (upper arrow) over origin of vertebral artery (lower arrow) as seen in fig 10a

vertebral and basilar arteries and their branches A difference in size between the right and left vertebral arteries is frequently seen Often a small vertebral artery does not reach the basilar artery but ends in the posterior inferior cerebellar artery (Fig 3) In some cases one vertebral artery may be absent and the other be of larger caliber Injection of contrast material into the right



a b

Fig 5 a) Right subclavian injection with head and neck turned to right side Tortuous large right vertebral artery with a fusiform aneurysm one centimeter above its origin (arrow) b) Left subclavian injection *Absence of left vertebral artery*

Fig 6 Injection of left subclavian artery *with tip of catheter just at its origin* Low origin of left vertebral artery at arch of aorta (arrow)

subclavian artery will readily show if the right vertebral artery is absent or occluded at its origin Sometimes the origin of the right vertebral artery is not demonstrated satisfactorily in a routine anteroposterior view following injection of the right subclavian artery because of superimposition of the right common carotid artery (see Fig 10a) A right posterior oblique view is then necessary to separate the vessels (Fig 4) Great care should be taken in diagnosing complete occlusion or absence of the left vertebral artery since it may originate in the arch of the aorta In such a case, injection of contrast material must be carried out with the tip of the catheter at the origin of the left subclavian artery In other cases the vessel may be demonstrated by injection of more *concentrated contrast material* (Angio Conray 80 %) *into the aortic arch* (Figs 5 and 6)

Arteriosclerotic occlusive disease of the extracranial and intracranial segments of the vertebral artery and occlusive lesions of the basilar artery or its branches are readily demonstrated with this technique (Figs 7 and 8)

Turning of the head and neck to one side in some patients may cause



Fig 7 Right subcla an inject on with head and eck turned to side f inject on Moderate stenos s of right ertebral artery at le el of sixth cerv cal v rtebra (lower arrow) and severe stenos s at its ntracrani l s gment (upper arrow)



Fig 8 Right subclavian injection Complete occlusion of left posterior ce ebral artery n an a p posit on of the head (arrow)

mechanical occlusion of the vertebral arteries in their distal or proximal extracranial segments Mechanical occlusion in the distal segment at the level of the atlanto-axial joint may occur on the side opposite that to which the head and neck are turned (Fig 9) On the other hand turning of the head and neck to the side in which the contrast material is injected may block the artery in the proximal segment (Fig 10) In other cases cervical osteophytes may compress the vertebral artery when the head and neck are turned to one side To be certain that narrowing or occlusion of the vertebral artery is due to extrinsic compression by musculoskeletal structures injection must be repeated with the head and neck in the neutral position or turned to the side opposite the mechanical compression Symptoms of vertebrobasilar insufficiency are




a b

Fig 5 a) Right subclavian injection with head and neck turned to right side Tortuous large right vertebral artery with a fusiform aneurysm one centimeter above its origin (arrow) b) Left subclavian injection Absence of left vertebral artery



Fig 6 Injection of left subclavian artery with tip of catheter just at its origin Low origin of left vertebral artery at arch of aorta (arrow)

subclavian artery will readily show if the right vertebral artery is absent or occluded at its origin Sometimes the origin of the right vertebral artery is not demonstrated satisfactorily in a routine anteroposterior view following injection of the right subclavian artery because of superimposition of the right common carotid artery (see Fig 10a) A right posterior oblique view is then necessary to separate the vessels (Fig 4) Great care should be taken in diagnosing complete occlusion or absence of the left vertebral artery since it may originate in the arch of the aorta In such a case, injection of contrast material must be carried out with the tip of the catheter at the origin of the left subclavian artery In other cases the vessel may be demonstrated by injection of more concentrated contrast material (Angio Conray 80 %) into the aortic arch (Figs 5 and 6)

Arteriosclerotic occlusive disease of the extracranial and intracranial segments of the vertebral artery and occlusive lesions of the basilar artery or its branches are readily demonstrated with this technique (Figs 7 and 8)

Turning of the head and neck to one side in some patients may cause



Fig 7 Right subclavian injection with head and neck turned to side of injection Moderate stenosis of right vertebral artery at level of sixth cervical vertebra (lower arrow) and severe stenosis at its intracranial segment (upper arrow)



Fig 8 Right subclavian injection Complete occlusion of left posterior cerebral artery in an a p position of the head (arrow)

mechanical occlusion of the vertebral arteries in their distal or proximal extracranial segments Mechanical occlusion in the distal segment at the level of the atlanto axial joint may occur on the side opposite that to which the head and neck are turned (Fig 9) On the other hand turning of the head and neck to the side in which the contrast material is injected may block the artery in the proximal segment (Fig 10) In other cases cervical osteophytes may compress the vertebral artery when the head and neck are turned to one side To be certain that narrowing or occlusion of the vertebral artery is due to extrinsic compression by musculoskeletal structures injection must be repeated with the head and neck in the neutral position or turned to the side opposite the mechanical compression Symptoms of vertebrobasilar insufficiency are experienced by these patients only when they rotate their head and neck to



a b

Fig 9 a) Bilateral simultaneous injection of subclavian arteries with head and neck turned to right Complete mechanical occlusion of left vertebral artery at level of atlanto axial joint (right arrow) and kinking of right vertebral artery at level of second cervical vertebra (left arrow) b) Bilateral simultaneous subclavian artery injection in same patient with head and neck turned to left The contrast material this time fills the intracranial segment of the left vertebral artery degree of kinking of right vertebral artery slightly diminished

one side The existence of a small, stenotic or kinked vertebral artery on one side is an important factor in precipitating symptoms when the vertebral artery on the opposite side is partially or completely blocked by turning of the head and neck

An intrinsic, localized arteriosclerotic lesion in the cervical course of the vertebral artery may simulate an extrinsic compression by a cervical osteophyte The intrinsic lesion may be readily differentiated because it does not change the form or caliber of the vessel when the head and neck are in different positions



Fig 10 a) Right subclavian injection with head and neck turned to right side Mechanical block of right vertebral artery between fifth and sixth cervical vertebrae (arrow) b) Left subclavian injection with head and neck turned to left side Mechanical block of left vertebral artery at its origin (arrow) c) Bilateral subclavian simultaneous injection in same patient with head and neck in neutral position Both vertebral arteries satisfactorily filled

Demonstration of intracranial saccular aneurysms of the vertebral and basilar arteries by simultaneous bilateral injection of the subclavian arteries has been very satisfactory in our experience In this way lamination of blood flow in the basilar artery is avoided, and the head may be moved at will to assist in demonstration of the neck of the aneurysm (Fig 11)

In cases of arteriovenous malformation injection of contrast material both into the anterior and into the posterior circulation of the brain is of primary importance when surgical treatment is contemplated In one of our patients with an arteriovenous malformation which filled from the right anterior choroidal artery its main feeding artery was a branch of the right posterior cerebral artery (Fig 12) Postoperative right internal carotid and right subclavian angiograms demonstrated that the malformation after clipping of the right anterior choroidal and posterior cerebral arteries was not filled with contrast material

Complications The complications in our series have all been local and minimal In 34 cases small intramural injections in the subclavian artery have

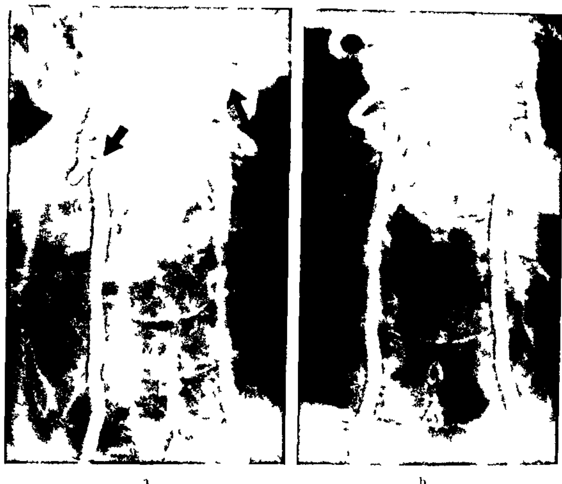


Fig 9 a) Bilateral simultaneous injection of subclavian arteries with head and neck turned to right Complete mechanical occlusion of left vertebral artery at level of atlanto axial joint (right arrow) and kinking of right vertebral artery at level of second cervical vertebra (left arrow) b) Bilateral simultaneous subclavian artery injection in same patient with head and neck turned to left The contrast material this time fills the intracranial segment of the left vertebral artery degree of kinking of right vertebral artery slightly diminished

one side The existence of a small, stenotic or kinked vertebral artery on one side is an important factor in precipitating symptoms when the vertebral artery on the opposite side is partially or completely blocked by turning of the head and neck

An intrinsic, localized arteriosclerotic lesion in the cervical course of the vertebral artery may simulate an extrinsic compression by a cervical osteophyte The intrinsic lesion may be readily differentiated because it does not change the form or caliber of the vessel when the head and neck are in different positions



Fig 10 a) Right subclavian injection with head and neck turned to right side Mechanical block of right vertebral artery between fifth and sixth cervical vertebrae (arrow) b) Left subclavian injection with head and neck turned to left side Mechanical block of left vertebral artery at its origin (arrow) c) Bilateral subclavian simultaneous injection in same patient with head and neck in neutral position Both vertebral arteries satisfactorily filled

Demonstration of intracranial saccular aneurysms of the vertebral and basilar arteries by simultaneous bilateral injection of the subclavian arteries has been very satisfactory in our experience In this way, lamination of blood flow in the basilar artery is avoided and the head may be moved at will to assist in demonstration of the neck of the aneurysm (Fig 11)

In cases of arteriovenous malformation injection of contrast material both into the anterior and into the posterior circulation of the brain is of primary importance when surgical treatment is contemplated In one of our patients with an arteriovenous malformation which filled from the right anterior choroidal artery its main feeding artery was a branch of the right posterior cerebral artery (Fig 12) Postoperative right internal carotid and right subclavian angiograms demonstrated that the malformation after clipping of the right anterior choroidal and posterior cerebral arteries was not filled with contrast material

Complications The complications in our series have all been local and minimal In 34 cases small intramural injections in the subclavian artery have



Fig 11 Bilateral subclavian simultaneous injection Aneurysm of bifurcation of basilar artery (arrow)

occurred Hematoma formation after removing the catheter has been easily prevented by compression of the subclavian artery in both the supraclavicular and infraclavicular regions Pneumothorax has occurred in 4 cases Injury of the brachial plexus, arteriovenous fistula, loss of brachial pulse, and cerebral complications have not been observed in this series

Conclusions

Angiography of the vertebrobasilar system by unilateral or bilateral simultaneous injection through infraclavicular catheterization of the subclavian artery has the following advantages

1 It is easy to carry out in a relatively short period of time



Fig 12 Lateral view of head following injection of right subclavian artery Arteriovenous malformation feeding from right posterior cerebral artery

2 It can be performed under local anesthesia in cooperative and alert patients

3 It provides satisfactory demonstration of abnormalities of the entire vertebrobasilar system and its terminal branches

4 It permits the head and neck to be turned in order to study mechanical occlusion of the vertebral artery caused by musculoskeletal structures

5 It provides a means for studying the extracranial and intracranial collateral circulation through the vertebrobasilar system in cases of occlusion of the internal carotid artery

6 It permits injection of contrast material into the lumen of the aortic arch for demonstration of the left vertebral artery when it has an anomalous origin from the arch itself

7 The complications have been local and minimal

SUMMARY

Direct percutaneous infraclavicular catheterization of the subclavian arteries for demonstration of the posterior cervico-cranial circulation is reported in a series of 414 patients Unilateral or bilateral simultaneous injection proved to be satisfactory for various types of abnormalities of the vertebrobasilar arterial system without the necessity of resorting to direct puncture of the vertebral arteries

ZUSAMMENFASSUNG

An einer Serie von 114 Fällen wurde die perkutane infraclaviculäre Katheterisierung der Art. subclavialis zur Aufzeigung der hinteren Gehirngefässe durchgeführt. Einseitige oder doppelseitige Simultanfüllung erwiesen sich als nützlich, so dass auf direkte Punktion der Vertebralarterien verzichtet werden konnte.

RÉSUMÉ

Présentation du cathétérisme sous claviculaire percutané direct des artères sous clavières sur une série de 114 sujets pour mettre en évidence la circulation cervico cranienne postérieure. L'injection unilatérale ou bilatérale simultanée ont donné satisfaction pour divers types d'anomalies du système artériel vertébro basilaire, sans qu'il soit nécessaire de ponctionner directement les artères vertébrales.

REFERENCES

FIELDS, W. S. and WEIBEL, J.: Effects of vascular disorders on the vestibular system. *In* Neurological aspects of auditory and vestibular disorders. W. S. Fields and B. R. Alford, eds. Springfield: Charles C Thomas (1964).

— —: Síntomas vertiginosos producidos por compresión extrínsica de las arterias vertebrales. Acta Neurol. Lat. Amer. 9 (1963), 328.

WEIBEL, J. and FIELDS, W. S.: Direct percutaneous infraclavicular catheterization of the subclavian artery. J. Neurosurg. 20 (1963), 233.

— —, BREITMAN, M. E., CRAWFORD, E. S. und KIRCHHOFF, P. G.: Panarteriographie der intra und extrakraniellen Zirkulation (Ergebnisse mit perkutaner Subclavia Katheterisation). Fortschr. Roentgenstr. 99 (1963), 3–4.

— —, CRAWFORD, E. S., DEBAKEY, M. E. and BEALL, A. C. Jr.: Clinical evaluation of Conray for angiography in patients with cerebrovascular disease. Amer. J. Roentgenol. 90 (1963), 1281.

WEIBEL, J. and FIELDS, W. S.: Angiografía de las afecciones vasculares cerebrales por cateterización infraclavicular de la arteria subclavia. *In* Cirurgia Vascular. Sosa Gallardo, ed. Barcelona, Spain (in press).

FROM THE ROENTGEN DEPARTMENT (DIRECTOR PROF ERIK LINDGREN) SERAFIMERLASARETTET AND THE NEURORADIOLOGICAL DEPARTMENT (DIRECTOR PROF TORGNY GREITZ) KAROLINSKA SJUKHUSET STOCKHOLM SWEDEN

ARTERIES OF THE BASAL GANGLIA

by

GUNNAR WESTBERG

Recent developments in medicine are making an increasing number of intracranial diseases available for therapy without the need for craniotomy The treatment of certain types of intracranial tumor by high dose supervoltic radiation with rotation (KRAMER McKISSOCK & CONCANNON 1961), the implantation of radioactive substances in cystic tumours (LEKSELL & LIDEN 1951 LINDGREN & WESTBERG 1964) and the treatment of malignant tumors with cytostatic agents are examples of these new possibilities Furthermore with the increasing use of hypothermia at operations, more advanced neuro surgical interventions have also become possible The demands for exactitude at the neuroradiologic examination both with respect to the nature and the extent of the pathologic process have become more stringent as a result of these developments It is often of vital importance to know how a process is related to the basal and central structures of the brain such information can seldom be obtained without an angiographic examination and close scrutiny of the gangliar vessels

Normal vascular anatomy of the basal ganglia

The investigation reported in this paper is based on the study of 50 corrosion specimens 100 normal cerebral angiographies and 20 angiographies on cadavers

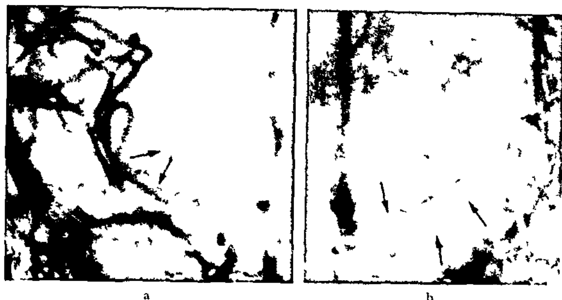


Fig. 1. Anatomical variations. a) The ganglial arteries from the middle cerebral artery are dominant (→). b) The ganglial arteries (Heubner's artery) from the anterior cerebral artery are dominant (→). The bifurcation site under the anterior perforated substance is concealed by the middle cerebral artery. In an earlier phase the branches appeared to spring directly from that artery.

ANDERSEN in a paper from 1958 describing the normal anatomy of the lenticulo-striate arteries as observed by him at cerebral angiographies, found that with few exceptions these vessels commence 'from the medial part of the middle cerebral artery'. He stressed their value in the angiographic diagnosis of atrophic and space-occupying processes. In a later paper in 1963, he described in more detail the appearance of the ganglial vessels in intracerebral hematoma.

The present author, in a study (1963) comparing the appearance of these vessels in roentgen films and autopsy specimens, reached a different conclusion concerning the normal anatomy. Many of the arterial branches which at the roentgen examination had seemed to start from the middle cerebral artery proved to be branches of Heubner's artery; others arose from the lateral part of the middle cerebral artery, starting with one to three main branches which ran close to the mother artery in a retrograde direction before curving off laterally to ramify on a level with the bifurcation, or immediately lateral to it. Consequently, these branches in some cases also appeared to arise directly from the middle cerebral artery, as the main branch of the ganglial vessels was often concealed by that artery in the projections commonly used for angiography. The vessels of the ganglia are not always correctly shown in modern textbooks of anatomy and neuroradiology either. They are often



Fig 2 Normal subject As both the posterior communicating arteries are filled with contrast medium both the anterior thalamo-perforating arteries (→) are visible The posterior thalamoperforating arteries (→→) are visible behind them

described as consisting of a medial and a lateral group springing from the middle cerebral artery The anatomist SHELLSHEAR in 1920 demonstrated that the medial part of the anterior perforated substance consists of perforations from a recurrent vessel originating in the anterior cerebral artery in the neighbourhood of the anterior communicating artery This recurrent vessel seems to be identical with the artery of Heubner The lateral perforations proved to have been caused by branches from the middle cerebral artery SHELLSHEAR also found a little group of small arteries situated more laterally than the commonly named lateral striate arteries and penetrating the base *of the brain in the limen insulae to reach the claustrum He called these the* claustral arteries and this observation is in agreement with my own findings in corrosion specimens of the brain arteries they are also occasionally seen in carotid angiograms under optimal conditions

Accordingly if the term lenticulostriate arteries' is to be retained it should be remembered that those vessels which usually are called the middle lenticulostriate arteries in the angiographic literature mainly consist of branches from Heubner s artery and thus arise from the anterior cerebral artery the lateral lenticulostriate arteries on the other hand mainly consist of branches from the middle cerebral artery To a certain extent a state of balance exists between the distribution of the branches from Heubner s artery and the ganglionar vessels *from the middle cerebral artery if the former artery* is small the branches from the middle cerebral artery predominate in number and



Fig 3 Hydrocephalus The posterior thalamo perforating arteries are elongated and are visible in the a p projection (→)

area of distribution (Fig 1a), whereas if the latter are few, and small, the branches from Heubner s artery are more prominent (Fig 1b) In the study of the corrosion specimens, branches from Heubner s artery often predominated without there being any corresponding signs of this at carotid angiography

The ganglıar vessels arising from the anterior and middle cerebral arteries are best demonstrated by serial angiography using the a p projection with the beam parallel to the floor of the anterior cranial fossa, the most suitable projection may vary slightly in the individual case, however The main stem of Heubner s artery, even when narrow, is usually well seen in the oblique projection In the lateral view, the ganglıar vessels have a fan like appearance

A number of small perforating arteries arise from the posterior communicating and posterior cerebral arteries and supply the thalamus and adjoining structures The naming of these vessels has also caused some confusion in the anatomical and radiologic literature, names such as prae mamillary or thalamo tuberal, retro mamillary or thalamo perforating, and thalamo geniculate arteries, are commonly encountered

Several small branches spring from the posterior communicating artery to run toward the base of the brain As a rule, one of these is larger than the others and is nearly always seen in the lateral projection, at rapid serial



Fig 4 Hydrocephalus. The ganglar arteries are displaced laterally (→)

angiography when the posterior communicating artery is filled with contrast medium Usually it is best seen at vertebral angiography (Fig 2) but some times it is visible at carotid angiography The writer calls this large vessel arising *from the posterior communicating artery the anterior thalamo perfor ating artery* Normally it runs obliquely upwards and backwards and penetra tes into the base of the brain lateral to the mamillary body, it ramifies within or immediately inside the lateral wall of the third ventricle and may be followed up to the level of the massa intermedia The anterior thalamo perforating artery supplies the outer anterior part of the thalamus

The posterior thalamo perforating arteries spring from the posterior cerebral artery Their appearance is that of a bunch of small arteries running in the interpeduncular fossa in the same direction as the anterior perforating artery they originate between the posterior communicating and basilar arteries perforating the base of the brain behind the mamillary bodies in the posterior perforated substance (Fig 2) and supplying among other things, the post erior portions of the thalamus Sometimes they spring almost entirely from one side but in many cases they arise from the posterior cerebral artery on both sides Some of the posterior twigs run to the mesencephalon The poste rior thalamo perforating arteries are also best seen in the lateral view in the ordinary a p half axial projection they are sometimes hidden by the



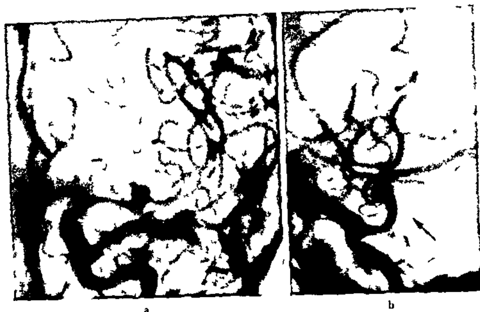
Fig 3 Hydrocephalus The posterior thalamo perforating arteries are elongated and are visible in the a p projection (←→)

area of distribution (Fig 1a), whereas if the latter are few, and small, the branches from Heubner's artery are more prominent (Fig 1b) In the study of the corrosion specimens, branches from Heubner's artery often predominated without there being any corresponding signs of this at carotid angiography

The ganglıar vessels arising from the anterior and middle cerebral arteries are best demonstrated by serial angiography using the a p projection with the beam parallel to the floor of the anterior cranial fossa, the most suitable projection may vary slightly in the individual case, however The main stem of Heubner's artery, even when narrow is usually well seen in the oblique projection In the lateral view, the ganglıar vessels have a fan like appearance

A number of small perforating arteries arise from the posterior communicating and posterior cerebral arteries and supply the thalamus and adjoining structures The naming of these vessels has also caused some confusion in the anatomical and radiologic literature names such as prae mamillary or thalamo tuberal, retro mamillary or thalamo perforating, and thalamo geniculate arteries, are commonly encountered

Several small branches spring from the posterior communicating artery to run toward the base of the brain As a rule one of these is larger than the others and is nearly always seen in the lateral projection, at rapid serial



a b

Fig 6 a) Arterial aneurysm of the middle cerebral artery The ganglial arteries which are displaced locally are seen close to the aneurysm b) The anterior thalamo-perforating artery springs from the top of an infundibular widening (→)

most lateral of the ganglial vessels has therefore proved to be a better point of reference for measurement of the distance to the midline (in the following called the ganglial vessel distance) and this principle was followed exclusively in the measurements undertaken in the present material Determinations were carried out in vivo on 72 hemispheres which were also examined by encephalography normal subjects and cases with symmetric dilatation of the ventricular system were studied The width of the lateral ventricles was assessed at encephalography by measuring the shortest distance from the inner upper angle of the lateral ventricle to the caudate nucleus in the a p pneumogram as well as the greatest transversal diameter in the same projection The former measure which according to KNUDSEN (1958) gives a better indication of ventricular size than the transversal diameter was used by GALLOWAY GREITZ & SJOGREN (1964) *when comparing the degree of ventricular dilatation with the distance* between the lateral choroidal and posterior pericallosal arteries in the lateral projection at vertebral angiography The author s measurements are shown in Fig 5 It emerges clearly from these diagrams that whatever the method used for calculation of ventricular size at encephalography there is a definite correlation between ventricular size and the ganglial vessel distance According

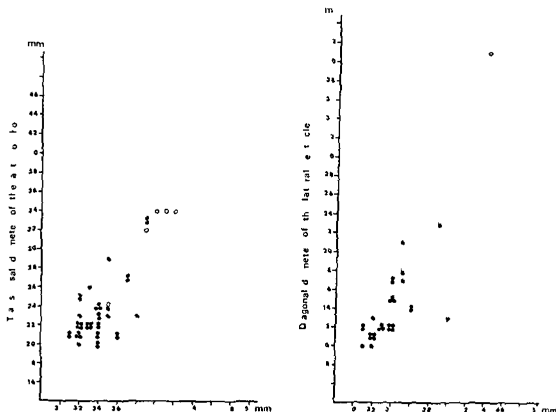


Fig. 5. Measurements showing ganglionar vessel distance. White circles denote cases with obstructive hydrocephalus.

vermis branches of the posterior inferior cerebellar artery and are then inaccessible for study. They are sometimes visible, for instance, in cases of hydrocephalus (Fig. 3).

The basal ganglia are also supplied with blood by small branches running from the anterior and posterior choroidal arteries.

Pathologic conditions

Dilatation of the lateral ventricles may be diagnosed by studying the ganglionar vessels, which are capable of being displaced laterally (Fig. 4). ANDERSEN (1958) measured the distance from the lenticulo striate arteries to the midline in normal patients and in cases with central and cortical atrophy, taking 'distance from midline of skull to most lateral point on the convexity of the curve of the most medial and the most lateral of the ventriculo striate arteries lying in the arterial fan'. The present author has found that the distance from the most medial of the arteries to the midline is difficult to assess, since the medial ganglionar vessels gradually decrease in size as they approach the midline, the

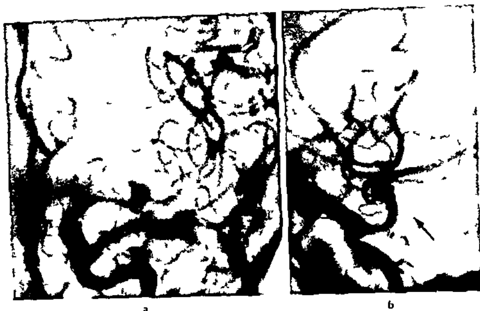


Fig 6 a) Arterial aneurysm of the middle cerebral artery The gangliar arteries which are displaced locally are close to the aneurysm b) The anterior thalamo-perforating artery springs from the top of an infundibular widening (→)

most lateral of the gangliar vessels has therefore proved to be a better point of reference for measurement of the distance to the midline (in the following called the gangliar vessel distance) and this principle was followed exclusively in the measurements undertaken in the present material Determinations were carried out in vivo on 72 hemispheres which were also examined by encephalography normal subjects and cases with symmetric dilatation of the ventricular system were studied The width of the lateral ventricles was assessed at encephalography by measuring the shortest distance from the inner upper angle of the lateral ventricle to the caudate nucleus in the a p pneumogram, as well as the greatest transversal diameter in the same projection The former measure which according to KNUDSEN (1958) gives a better indication of ventricular size than the transversal diameter was used by GALLOWAY, GREITZ & SJOGREN (1964) when comparing the degree of ventricular dilatation with the distance between the lateral choroidal and posterior pericallosal arteries in the lateral projection at vertebral angiography The author s measurements are shown in Fig 5 It emerges clearly from these diagrams that whatever the method used for calculation of ventricular size at encephalography there is a definite correlation between ventricular size and the gangliar vessel distance According



Fig 7 Two arteriovenous malformations supplied only through the ganglar arteries a) Heubner s artery Subtraction film b) The posterior thalamo perforating arteries



Fig 8 An arteriovenous malformation partly supplied through a greatly dilated ganglar artery from the middle cerebral artery



Fig. 9. Intracerebral hemorrhage. a) Postmortem angiography with a water soluble contrast medium. The medium has leaked from the ganglionar arteries to the hematoma (→). b) A specimen from the same case. The Sylvian fissure is markedly displaced in a lateral direction.

to these calculations the ganglionar vessel distance agrees better with the greatest transversal diameter of the anterior horn than with the diagonal diameter. The greater the size of the lateral ventricles the better is the correlation.

Vascular disease. A knowledge of the special anatomy of the basal ganglionar arteries is important in operations for arterial aneurysm. As the origin of these vessels often lies close to aneurysms on the main brain arteries they run a considerable risk of being damaged at the operation with grave neurologic deficits as a result. The operative risks are increased if the ganglionar vessels are seen at angiography to be situated near the aneurysm (Fig. 6 a). When infundibular widening is present a narrow little artery is sometimes seen running from its apex obliquely and backwards. This is usually the anterior perforate artery (Fig. 6b). If an infundibulum is considered to be due to an aneurysm and is treated surgically there is a risk that trophic damage will arise in the basal ganglia or the thalamus. Small intracerebral hemorrhages which are common occurrences in association with subarachnoid bleeding, often appear as a local displacement at the level of the aneurysm (Fig. 6a).



Fig. 7 Two arteriovenous malformations supplied only through the ganglionic arteries a) Heubner's artery Subtraction film b) The posterior thalamo perforating arteries



Fig. 8 An arteriovenous malformation partly supplied through a greatly dilated ganglionic artery from the middle cerebral artery



a b

Fig 9 Intracerebral hemorrhage a) Postmortem angiography with a water soluble contrast medium The medium has leaked from the ganglar arteries to the hematoma (→) b) A specimen from the same case The Sylvian fissure is markedly displaced in a lateral direction

to these calculations the ganglar vessel distance agrees better with the greatest transversal diameter of the anterior horn than with the diagonal diameter The greater the size of the lateral ventricles the better is the correlation

Vascular disease A knowledge of the special anatomy of the basal ganglar arteries is important in operations for arterial aneurysm As the origin of these vessels often lies close to aneurysms on the main brain arteries they run a considerable risk of being damaged at the operation with grave neurologic deficits as a result The operative risks are increased if the ganglar vessels are seen at angiography to be situated near the aneurysm (Fig 6 a) When infundibular widening is present a narrow little artery is sometimes seen running from its apex obliquely and backwards This is usually the anterior perforate artery (Fig 6b) If an infundibulum is considered to be due to an aneurysm and is treated surgically there is a risk that trophic damage will arise in the basal ganglia or the thalamus Small intracerebral hemorrhages which are common occurrences in association with subarachnoid bleeding often appear as a local displacement at the level of the aneurysm (Fig 6a)



Fig 7 Two arteriovenous malformations supplied only through the ganglar arteries a) Heubner's artery Subtraction film b) The posterior thalamo perforating arteries



Fig 8 An arteriovenous malformation partly supplied through a greatly dilated ganglar artery from the middle cerebral artery



Fig 9 Intracerebral hemorrhage a) Postmortem angiography with a water soluble contrast medium The medium has leaked from the ganglar arteries to the hematoma (→) b) A specimen from the same case The Sylvian fissure is markedly displaced in a lateral direction

to these calculations the ganglar vessel distance agrees better with the greatest transversal diameter of the anterior horn than with the diagonal diameter The greater the size of the lateral ventricles the better is the correlation

Vascular disease A knowledge of the special anatomy of the basal ganglar arteries is important in operations for arterial aneurysm As the origin of these vessels often lies close to aneurysms on the main brain arteries they run a considerable risk of being damaged at the operation with grave neurologic deficits as a result The operative risks are increased if the ganglar vessels are seen at angiography to be situated near the aneurysm (Fig 6 a) When infundibular widening is present, a narrow little artery is sometimes seen running from its apex obliquely and backwards This is usually the anterior perforate artery (Fig 6b) If an infundibulum is considered to be due to an aneurysm and is treated surgically there is a risk that trophic damage will arise in the basal ganglia or the thalamus Small intracerebral hemorrhages which are common occurrences in association with subarachnoid bleeding often appear as a local displacement at the level of the aneurysm (Fig 6a)

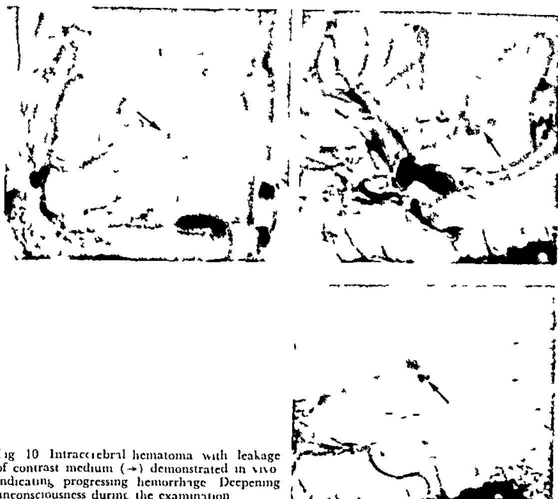


Fig. 10. Intracerebral hematoma with leakage of contrast medium (→) demonstrated in vivo indicating progressing hemorrhage. Deepening unconsciousness during the examination.

Arteriovenous malformations involve the arteries of the basal ganglia both directly and indirectly via collaterals. An arteriovenous malformation in which Heubner's artery was the only afferent vessel is shown in Fig. 7a, while in Fig. 7b is seen a malformation supplied by the posterior thalamo-perforating arteries. Because of the risk of central necrosis neither of these patients were operated upon.

Expanding lesions. The appearance of the ganglionar vessels often allows fairly accurate assessment of the location and extension of expansive processes in and near the basal ganglia. This is especially true in the case of central and temporal lesions, but a study of these small arteries often gives information of value about processes in the parietal and frontal regions. ANDERSEN has discussed the displacement of the ganglionar vessels in intracerebral hemorrhage. He pointed out that the small ganglionar arteries may show considerable

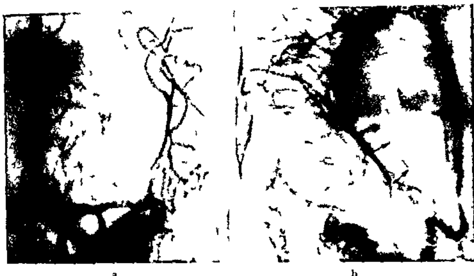


Fig. 11 Temporal expansive processes a) Intracerebral tumor infiltrating the basal ganglia. The distance between the ganglar and the Sylvian arteries is increased and the latter vessels are displaced medially b) Extracerebral tumor. Both Sylvian and ganglar arteries displaced medially and distance between them decreased



Fig. 12 Parietal astrocytoma. The ganglar arteries are displaced basally and medially

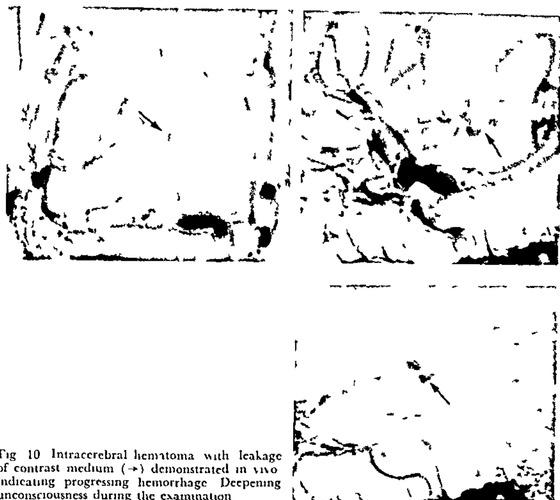


Fig 10 Intracerebral hematoma with leakage of contrast medium (→) demonstrated in vivo indicating progressing hemorrhage Deepening unconsciousness during the examination

Arteriovenous malformations involve the arteries of the basal ganglia both directly and indirectly via collaterals An arteriovenous malformation in which Heubner s artery was the only afferent vessel is shown in Fig 7a, while in Fig 7b is seen a malformation supplied by the posterior thalamo perforating arteries Because of the risk of central necrosis neither of these patients were operated upon

Expanding lesions The appearance of the ganglial vessels often allows fairly accurate assessment of the location and extension of expansive processes in and near the basal ganglia This is especially true in the case of central and temporal lesions, but a study of these small arteries often gives information of value about processes in the parietal and frontal regions ANDERSEN has discussed the displacement of the ganglia vessels in intracerebral hemorrhage He pointed out that the small ganglia arteries may show considerable

Fig 14 Upward herniation The anterior and posterior thalamo-perforating arteries are elongated and displaced in a forward direction

apart An increase of the distance between the Sylvian and the ganglial vessels in infiltrating temporal and central tumors is usually a sign that the tumor is growing in both a temporal and a central direction in the basal ganglia (Fig 11a) A similar increase in this distance may also be seen in other conditions however it is seen for example as a side phenomenon of lateral herniation of the cerebral hemisphere under the falx in cases with large frontal and occipital processes The distance is also increased in basal, extracerebral tumors since the tumor can displace the insula region medially and adjoining parts of the temporal lobe laterally A decreased or unchanged distance between the Sylvian and the ganglial vessels in conjunction with medial displacement of both these groups of vessels is often seen in cases with extracerebral processes in the anterior and lateral part of the temporal region at the level of the basal ganglia This type of dislocation is seen for example, in a hygroma (Fig 11b) The latter condition if located in the anterior and lateral temporal region is sometimes difficult to distinguish in an ordinary a p view If the ganglial vessels arising from the anterior and middle cerebral arteries as well as the Sylvian arteries are displaced medially and the distance between the two groups of arteries is not increased then the presence of a laterally situated extracerebral process should be suspected and suitable oblique views taken Similarly if an extracerebral hematoma has been diagnosed intracerebral hemorrhage in the temporal lobe should be suspected if the distance between the Sylvian and the ganglial vessels is increased If an



Fig. 13. Thalamic tumor. a) Vertebral angiography. The thalamo perforating arteries are elongated and the anterior thalamo perforating artery (→) leaves the posterior communicating artery at right angles. b) Carotid angiography. The elongated displaced anterior thalamo perforating artery is also seen at carotid angiography. This was the only sign of a tumor in the thalamus at this examination.

displacement even in cases where the superficial vessels are not noticeably out of position. He also noted that hemorrhages which do not perforate into the ventricular system may cause a fair degree of displacement even if they are small; with regard to hemorrhages perforating into the ventricular system, he stated that the displacement of the pericallosal and/or middle cerebral arteries is insignificant and within normal variations. The present author does not entirely share his opinion. True, the pericallosal artery usually is then situated in the midline, or is only slightly displaced, but the middle cerebral arteries as a rule are curved and elongated, and displaced laterally towards the calotte. Fig. 9, a and b shows a case in point, in which the angiography had been carried out post mortem and the injected contrast medium had leaked out into the hematoma. Leakage of contrast substance into the hematoma may also occur in vivo (Fig. 10).

The ganglia arteries often show characteristic changes in different forms of intracerebral and extracerebral expansive processes. A tumour which has originated in the basal ganglia and has not yet become especially large may manifest itself solely as a deformation and pushing apart of the basal ganglia arteries without any other signs of dislocation of the larger vessels; if it has also infiltrated into the temporal lobe the Sylvian vessels as well are forced



Fig 14 Upward herniation The anterior and posterior thalamo-perforating arteries are elongated and displaced in a forward direction

apart An increase of the distance between the Sylvian and the ganglar vessels in infiltrating temporal and central tumors is usually a sign that the tumor is growing in both a temporal and a central direction in the basal ganglia (Fig 11a) A similar increase in this distance *may also be seen in* other conditions however it is seen for example as a side phenomenon of lateral herniation of the cerebral hemisphere under the falx in cases with large frontal and occipital processes The distance is also increased in basal extracerebral tumors, since the tumor can displace the insula region medially and adjoining parts of the temporal lobe laterally A decreased or unchanged distance between the Sylvian and the ganglar vessels in conjunction with medial displacement of both these groups of vessels is often seen in cases with *extracerebral processes in the anterior and lateral part of the temporal region* at the level of the basal ganglia This type of dislocation is seen for example in a hygroma (Fig 11b) The latter condition if located in the anterior and lateral temporal region is sometimes difficult to distinguish in an ordinary a p view If the ganglar vessels arising from the anterior and middle cerebral arteries as well as the Sylvian arteries are displaced medially and the distance between the two groups of arteries is not increased then the presence of a laterally situated extracerebral process should be suspected and suitable oblique views taken Similarly if an extracerebral hematoma has been diagnosed intracerebral hemorrhage in the temporal lobe should be suspected if the distance between the Sylvian and the ganglar vessels is increased If an



a b

Fig. 13. Thalamic tumor. a) Vertebral angiography. The thalamo-perforating arteries are elongated and the anterior thalamo-perforating artery (←) leaves the posterior communicating artery at right angles. b) Carotid angiography. The elongated displaced anterior thalamo-perforating artery is also seen at carotid angiography. This was the only sign of a tumor in the thalamus at this examination.

displacement even in cases where the superficial vessels are not noticeably out of position. He also noted that hemorrhages which do not perforate into the ventricular system may cause a fair degree of displacement even if they are small; with regard to hemorrhages perforating into the ventricular system he stated that "the displacement of the pericallosal and/or middle cerebral arteries is insignificant and within normal variations". The present author does not entirely share his opinion. True, the pericallosal artery usually is then situated in the midline, or is only slightly displaced, but the middle cerebral arteries as a rule are curved and elongated, and displaced laterally towards the calotte. Fig. 9, a and b shows a case in point, in which the angiography had been carried out post mortem and the injected contrast medium had leaked out into the hematoma. Leakage of contrast substance into the hematoma may also occur in vivo (Fig. 10).

The ganglia arteries often show characteristic changes in different forms of intracerebral and extracerebral expansive processes. A tumour which has originated in the basal ganglia and has not yet become especially large may manifest itself solely as a deformation and pushing apart of the basal ganglia arteries without any other signs of dislocation of the larger vessels; if it has also infiltrated into the temporal lobe the Sylvian vessels as well are forced



Fig 14 Upward herniation The anterior and posterior thalamo-perforating arteries are elongated and displaced in a forward direction

apart An increase of the distance between the Sylvian and the ganglıar vessels in infiltrating temporal and central tumors, is usually a sign that the tumor is growing in both a temporal and a central direction in the basal ganglia (Fig 11a) A similar increase in this distance may also be seen in other conditions however, it is seen for example as a side phenomenon of lateral herniation of the cerebral hemisphere under the falx in cases with large frontal and occipital processes The distance is also increased in basal extracerebral tumors since the tumor can displace the insula region medially and adjoining parts of the temporal lobe laterally A decreased or unchanged distance between the Sylvian and the ganglıar vessels in conjunction with medial displacement of both these groups of vessels is often seen in cases with extracerebral processes in the anterior and lateral part of the temporal region at the level of the basal ganglia This type of dislocation is seen for example in a hygroma (Fig 11b) The latter condition if located in the anterior and lateral temporal region is sometimes difficult to distinguish in an ordinary a p view If the ganglıar vessels arising from the anterior and middle cerebral arteries as well as the Sylvian arteries are displaced medially and the distance between the two groups of arteries is not increased then the presence of a laterally situated *extracerebral process should be suspected* and suitable oblique views taken Similarly if an extracerebral hematoma has been diagnosed intracerebral hemorrhage in the temporal lobe should be suspected if the distance between the Sylvian and the ganglıar vessels is increased If an

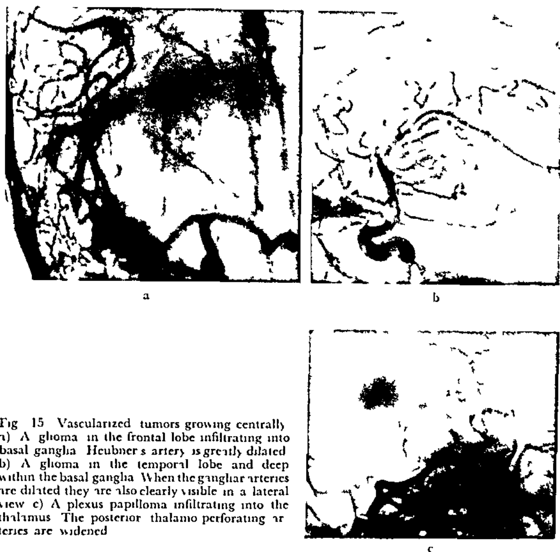


Fig 15 Vascularized tumors growing centrally a) A glioma in the frontal lobe infiltrating into basal ganglia Heubner's artery is greatly dilated b) A glioma in the temporal lobe and deep within the basal ganglia When the gangliar arteries are dilated they are also clearly visible in a lateral view c) A plexus papilloma infiltrating into the thalamus The posterior thalamo perforating arteries are widened

expanding process is present parietally the gangliar arteries will be compressed and displaced basally and medially (Fig 12)

Central tumors growing in the thalamus region cause a characteristic elongation and displacement of the thalamo perforating arteries, and in such cases the angle between the anterior thalamo perforating and posterior communicating arteries, which normally is sharp and opens backwards, is often widened (Fig 13, a and b) The anterior and posterior thalamo perforating arteries may even both point anteriorly A similar change in direction may also be seen in upward herniation through the tentorial notch in cases with expanding processes in the posterior cranial fossa (Fig 14) Although the anterior thalamo perforating artery is very small, it is of considerable

importance in the diagnosis of processes in the thalamus region At a carotid angiography with apparently normal findings, an elongation of this vessel in conjunction with enlargement of the angle with the posterior communicating artery may be the only sign but a very clear one, of a pathologic process in the thalamus (Fig 13b)

In highly vascularized tumors the gangliar vessels become increasingly dilated as the tumor infiltrates into the central and basal parts of the brain Widening of Heubner s artery may be an indication that the tumor is also growing into the anterior part of the basal ganglia and internal capsule (Fig 15a) If the tumor is located a little farther back and higher up the ganglar vessels from the middle cerebral artery will also be dilated and de formed (Fig 15b) and if it is in the thalamus region the posterior thalamo-perforating arteries are dilated (Fig 15c)

SUMMARY

The normal roentgenographic anatomy of the arteries of the basal ganglia and their appe arance in different pathologic conditions in the brain are described It is of value to study not only the ganglar vessels springing from the anterior cerebral and middle cerebral arteries but also those which arise from the posterior communicating and posterior cerebral arteries

ZUSAMMENFASSUNG

Es wird die normale Rontgenanatomie der Arterien der basalen Ganglien und ihr Aussehen bei verschiedenen pathologischen Zustanden beschrieben Es ist wichtig nicht nur die Gefässe die von der art cerebr ant *und media sondern auch die die von der art communicans post* und von den art cerebr post entspringen zu studieren

RÉSUMÉ

Description de l anatomie radiologique normale des artères des noyaux gris centraux et de leur aspect dans diverses affections cérébrales Il importe d étudier non seulement les artères des noyaux gris qui provennent des arteres cerébrales antérieure et moyenne mais *aussi celles* qui viennent des arteres communicante postérieure et cérébrale postérieure

REFERENCES

ANDERSEN POLL E The lenticulo-striate arteries and their diagnostic value A preliminary report Acta radiol 50 (1958) 84

— Angiographic localization of small intracerebral hematomas Acta radiol New series Diagnosis 1 (1963) 173

CRITCHELEY MACDONALD The anterior cerebral artery and its syndromes Brain 53 (1930) 120

KNUDSEN, P A Ventriklernes størrelseforhold i anatomisk normale hjerner fra voksne mennesker (Danish) Andersbogtrykkeriet, Odense 1958
GALLOWAY J R GREITZ T and SJÖGREN S E Vertebral angiography in the diagnosis of ventricular dilatation Acta radiol New Series Diagnosis 2 (1964) 321
KRAMER, S McKISSOCK W and CONCANNON J P Craniopharyngeomas Treatment by combined surgery and radiation therapy J Neurosurg 18 (1961) 217
LEKSELL L and LIDEN K A therapeutic trial with radioactive isotopes in cystic brain tumor In Radioisotope Techniques Vol I Medical and physiological applications (= Proc Isotope Techniques Confer Oxford July 1951) H M Stationery Office, London 1951
LINDGREN E and WESTBERG G Radioactive bismuth phosphate for the treatment of craniopharyngioma Acta radiol New Series Therapy physics biology 2 (1964) 113
WESTBERG G The recurrent artery of Heubner and the arteries of the central ganglia Acta radiol New series Diagnosis 1 (1963) 949

AUS DER NEUROCHIRURGISCHEN UNIVERSITÄTSKLINIK (DIREKTOR PROF. H. W. PIA), GIESSEN/LAHN, DEUTSCHLAND

DAS CAROTISANGIOGRAMM BEI DEN EINSEITIG FRÜHKINDLICHEN HIRNSCHÄDIGUNGEN

von

HEINZGEORG VOGELSANG

Die Diagnose einer Hemiatrophia cerebri gewinnt bei dem heutigen Stande der Neurochirurgie zunehmend an Bedeutung. Maßnahmen wie die Hemisphärektomie vermögen das meist mit der spastischen Halbseitenlähmung vergesellschaftete Anfallsleiden und die dadurch bedingte zunehmende Wesensänderung zum sistieren zu bringen; in vielen Fällen gelingt dann ein Aufholen des geistigen Entwicklungsrückstandes und eine soziale Eingliederung.

Wenn auch heute noch die Encephalographie unter den diagnostischen Maßnahmen an erster Stelle steht, da sie u. a. eine Aussage über die vom Operateur geforderte halbseitige Schädigung gestattet, so hat doch die cerebrale Angiographie den Vorteil, in vielen Fällen die Ursache der Schädigung aufzudecken und somit einen Beitrag zur Pathogenese zu leisten. Die zunehmende technische Verbesserung der Serienangiographie und der Narkose gestatten es heute ohne erhöhtes Risiko auch Kleinkinder und Säuglinge dieser Untersuchung zu unterziehen und so schon frühzeitig gefässabhängige cerebrale Schädigungen festzustellen. Derartige Gehirnschädigungen im Kindesalter sind seit den grundlegenden pathologisch-anatomischen Arbeiten

Tabelle

Übersicht der erhobenen angiographischen Befunde (unter Berücksichtigung des Entstehungszeitpunktes)

Gesamtzahl der Angiogramme (36)

Befund	Anzahl	Entstehungszeitpunkt	Anzahl
Verschluss der A. cerebri med.	(6)	pränatal	(10)
Teilausfall der A. cerebri med.	(5)	natal	(Ø)
Dünnkalibrige Arterien	(6)	postnatal	(7)
Arachnoidalzysten	(3)		
Verziehung von Art. zur atrophischen Seite	(9)	pränatal	(Ø)
		natal	(1)
Normal	(7)	postnatal	(12)

von HALLERVORDEN, MEYER, SCHWARTZ & FINK lange bekannt, 1961 von BANKER nochmals bearbeitet worden. Angiographisch konnte bereits 1952 PICAZA an Kindern derartige Gefässausfälle nachweisen, später folgten Publikationen von ACHSLOGH & SAINTES, KUNDRATITZ und Mitarb., POSER & TAVERAS, ROSEGAY & WELCH, TAVERAS & POSER, VIGOUROUX et coll., WALTER & BRANDT zu diesem Thema. Die bisher umfassensten Arbeiten über angiographische Befunde bei frühkindlichen Hemiplegien erbrachten 1956 LEFEBVRE et coll. sowie 1964 DYKEN. Nahezu 50 % der 70 untersuchten Kinder zeigten einen Ausfall bzw. Veränderungen an grossen Arterien, vorwiegend die A. cerebri und ihre Äste betreffend, z. T. mit Kollateralkreisläufen wie sie beim Erwachsenen bekannt sind.

Da sich unsere Klinik unter anderem speziell mit den Problemen der infantilen Hemiplegie (LANG, PIA) und deren operative Behandlung durch die Hemisphärektomie (PIA) befasst, lag es nahe unser eigenes Material mit der Frage der Wertigkeit der Carotisangiographie und ihrer Ergebnisse zu überprüfen.

Es wurden 36 Angiogramme ausgewertet (20 weibliche und 16 männliche Pat. im Alter zwischen 4 Wochen und 35 Jahren). 17 Male war die linke, 19 Male die rechte Grosshirnhemisphäre die geschädigte. 16 der Fälle zeigten entweder einen ganz unauffälligen Befund (7 Fälle) oder nur eine Verziehung von Arterien und Venen zur atrophischen Seite hin (9 Fälle). Dreimal fand sich eine Arachnoidalzyste. Bei den übrigen 17 Angiogrammen fanden sich Veränderungen an den Arterien selbst und zwar in 6 Fällen ein kompletter Verschluss der A. cerebri med. (zweimal als Aplasie imponierend), in 5 Fällen ein Ausfall grösserer Äste bzw. Gruppen von Nebenästen dieser Hauptarterie und weitere 6 Fälle zeigten auffällig dünnkalibrig, z. T. wie rarefiziert



Abb 1 Hemiatrophia cerebri Ausfall der A cerebri med

wirkende Arterien der Mediagruppe Nur in einem Fall fand sich neben einem *Ausfall von Arterien des Mediabereiches mit* Kollateralkreislaufen auch ein Fehlen oberflachlicher Hirnvenen fronto parietal und Nichtdarstellung des Sinus sag sup in seinem vorderen Anteil

Diese angiographischen Befunde bedurfen aber in mehrfacher Hinsicht noch weiterer Erorterungen Da ist einmal der Zeitpunkt der Entstehung derartiger Gefassveranderungen Unter den 17 Fallen mit pathologischen Angiogrammen war die Schadigung in 10 als in der Pranatalperiode und in 7 Fallen als postnatal entstanden anzusehen Kein Fall ist dabei der mit Überzeugung in die Geburtsperiode zu verlegen ist Dem gegenuber stehen unter den Fallen bei denen die Angiographie normal ausfiel bzw nur eine Verziehung von Gefassen zur Gegenseite aufwies in 4 Fallen eine Schadigung unter der Geburt und in 12 Fallen postnatal, jedoch keiner im Pranatalzeitraum Diese Auffalligkeiten stimmen mit pathologisch anato mischen Ergebnissen uberein nach denen geburtsbedingte Fruh und Spat schadigungen vorwiegend doppelseitige Ausfalle hervorrufen und die arteri elle Gefasschadigung als Ursache der infantilen Hemiplegie vorwiegend pranatal entsteht Auf Grund seiner Erfahrung an inzwischen 80 ausgewerteten infantilen Hemiplegien neigt PIA auch dazu eine pranatale Entstehung bei uberwiegend schleichendem und negativen Verlausformen mit Fehlen jeg licher atiologischer Hinweise anzunehmen Unsere gefassabhangigen Schadi gungen zeigten nahezu alle einen derartigen Verlauf Als Ursachen derartiger G fassschadigungen haben Embolien bei Infektionskrankheiten sonstigen Infekten oder Herzerkrankungen (BANKER FORD MAIR WIESEL u a) zu gelten Ferner lokale oder allgemeine Gefasserkrankungen mit Thrombosie rungen Degenerationen Fibroblastosen (BANKER, FIELD, STEVENS WISOFF

Tabelle

Übersicht der erhobenen angiographischen Befunde (unter Berucksichtigung des Entstehungszeitpunktes)

Gesamtzahl der Angiogramme (36)

Befund	Anzahl	Zeitpunkt	Anzahl
Verschluss der A cerebri med	(6)	pranatal	(10)
Teilausfall der A cerebri med	(5)	natal	(∅)
Dunnkalibrige Arterien	(6)	postnatal	(7)
Arachnoidalzysten	(3)		
Verziehung von Art zur atrophischen Seite	(9)	pranatal	(∅)
		natal	(1)
Normal	(7)	postnatal	(12)

von HALLERVORDEN, MEYER, SCHWARTZ & FINK lange bekannt, 1961 von BANKER nochmals bearbeitet worden Angiographisch konnte bereits 1952 PICAZA an Kindern derartige Gefassausfalle nachweisen, spater folgten Publikationen von ACHSLOGH & SAINTES, KUNDRATITZ und Mitarb , POSER & TAVERAS, ROSEGAY & WELCH, TAVERAS & POSER, VIGOUROUX et coll , WALTER & BRANDT zu diesem Thema Die bisher umfassensten Arbeiten uber angiographische Befunde bei fruhkindlichen Hemiplegien erbrachten 1956 LEFEBVRE et coll sowie 1964 DYKEN Nahezu 50 % der 70 untersuchten Kinder zeigten einen Ausfall bzw Veranderungen an grossen Arterien, vorwiegend die A cerebri und ihre Aste betreffend, z T mit Kollateralkreislaufen wie sie beim Erwachsenen bekannt sind

Da sich unsere Klinik unter anderem speziell mit den Problemen der infantilen Hemiplegie (LANG, PIA) und deren operative Behandlung durch die Hemispharektomie (PIA) befasst, lag es nahe unser eigenes Material mit der Frage der Wertigkeit der Carotisangiographie und ihrer Ergebnisse zu uberprufen

Es wurden 36 Angiogramme ausgewertet (20 weibliche und 16 mannliche Pat im Alter zwischen 4 Wochen und 35 Jahren) 17 Male war die linke, 19 Male die rechte Grosshirnhemisphare die geschadigte 16 der Falle zeigten entweder einen ganz unauffalligen Befund (7 Falle) oder nur eine Verziehung von Arterien und Venen zur atrophischen Seite hin (9 Falle) Dreimal fand sich eine Arachnoidalzyste Bei den ubrigen 17 Angiogrammen fanden sich Veranderungen an den Arterien selbst und zwar in 6 Fallen ein kompletter Verschluss der A cerebri med (zweimal als Aplasie imponierend), in 5 Fallen ein Ausfall grosserer Aste bzw Gruppen von Nebenasten dieser Hauptarterie und weitere 6 Falle zeigten auffallig dunnkalibrig, z T wie rarefiziert



Abb 1 Hemiatrophia cerebri Ausfall der A cerebri med

wirkende Arterien der Mediagruppe Nur in einem Fall fand sich neben einem Ausfall von Arterien des Mediabereiches mit Kollateralkreislaufen auch ein Fehlen oberflachlicher Hirnvenen fronto parietal und Nichtdarstellung des Sinus sag sup in seinem vorderen Anteil

Diese angiographischen Befunde bedurfen aber in mehrfacher Hinsicht noch weiterer Erorterungen Da ist einmal der Zeitpunkt der Entstehung derartiger Gefässveranderungen Unter den 17 Fallen mit pathologischen Angiogrammen war die Schadigung in 10 als in der Pranatalperiode und in 7 Fallen als postnatal entstanden anzusehen Kein Fall ist dabei der mit Überzeugung in die Geburtsperiode zu verlegen ist Dem gegenuber stehen unter den Fallen bei denen die Angiographie normal ausfiel bzw nur eine Verziehung von Gefassen zur Gegenseite aufwies in 4 Fallen eine Schadigung unter der Geburt und in 12 Fallen postnatal, jedoch keiner im Pranatalzeitraum Diese Auffalligkeiten stimmen mit pathologisch anatomischen Ergebnissen uberein nach denen geburtsbedingte Fruh und Spat schadigungen vorwiegend doppelseitige Ausfalle hervorrufen und die arteriElle Gefasschadigung als Ursache der infantilen Hemiplegie vorwiegend pranatal entsteht Auf Grund seiner Erfahrung an inzwischen 80 ausgewerteten infantilen Hemiplegien neigt PIA auch dazu eine pranatale Entstehung bei uberwiegend schleichendem und negativen Verlausformen mit Fehlen jeglicher atiologischer Hinweise anzunehmen Unsere gefassabhangigen Schadigungen zeigten nahezu alle einen derartigen Verlauf Als Ursachen derartiger Gefässschadigungen haben Embolien bei Infektionskrankheiten sonstigen Infekten oder Herzerkrankungen (BANKER FORD MAIR WIESEL u a) zu gelten Ferner lokale oder allgemeine Gefasserkrankungen mit Thrombosierungen Degenerationen Fibroblastosen (BANKER FIELD STEVENS WISOFF

Tabelle

Übersicht der erhobenen angiographischen Befunde (unter Berücksichtigung des Entstehungszeitpunktes)

Gesamtzahl der Angiogramme (36)

Befund	Anzahl	Entstehungszeitpunkt	Anzahl
Verschluss der A cerebri med	(6)	pränatal	(10)
Teilausfall der A cerebri med	(5)	natal	(∅)
Dünnkalibrige Arterien	(6)	postnatal	(7)
Arachnoidalzysten	(3)		
Verziehung von Art zur atrophischen Seite	(9)	pränatal	(∅)
		natal	(1)
Normal	(7)	postnatal	(12)

von HALLERVORDEN, MEYER, SCHWARTZ & FINK lange bekannt, 1961 von BANKER nochmals bearbeitet worden Angiographisch konnte bereits 1952 PICAZA an Kindern derartige Gefassausfälle nachweisen, spater folgten Publikationen von ACHSLOGH & SAINTES, KUNDRATITZ und Mitarb, POSER & TAVERAS, ROSEGAY & WELCH, TAVERAS & POSER, VIGOUROUX et coll, WALTER & BRANDT zu diesem Thema Die bisher umfassensten Arbeiten uber angiographische Befunde bei fruhkindlichen Hemiplegien erbrachten 1956 LEFEBVRE et coll sowie 1964 DYKEN Nahezu 50 % der 70 untersuchten Kinder zeigten einen Ausfall bzw Veranderungen in grossen Arterien, vorwiegend die A cerebri und ihre Aste betreffend, z T mit Kollateralkreislaufen wie sie beim Erwachsenen bekannt sind

Da sich unsere Klinik unter anderem speziell mit den Problemen der infantilen Hemiplegie (LANG, PIA) und deren operative Behandlung durch die Hemisphärektomie (PIA) befasst, lag es nahe unser eigenes Material mit der Frage der Wertigkeit der Carotisangiographie und ihrer Ergebnisse zu uberprufen

Es wurden 36 Angiogramme ausgewertet (20 weibliche und 16 mannliche Pat im Alter zwischen 4 Wochen und 35 Jahren) 17 Male war die linke, 19 Male die rechte Grosshirnhemisphare die geschadigte 16 der Falle zeigten entweder einen ganz unauffalligen Befund (7 Falle) oder nur eine Verziehung von Arterien und Venen zur atrophischen Seite hin (9 Falle) Dreimal fand sich eine Arachnoidalzyste Bei den ubrigen 17 Angiogrammen fanden sich Veranderungen an den Arterien selbst und zwar in 6 Fallen ein kompletter Verschluss der A cerebri med (zweimal als Aplasie imponierend) in 5 Fallen ein Ausfall grosserer Aste bzw Gruppen von Nebenasten dieser Hauptarterie und weitere 6 Falle zeigten auffallig dunnkalibrig z T wie rarefiziert



Abb 3 Hemiatrophia cerebri Auffallend dunnkalibrige Arterien der gesamten Mediagruppe (a) im Vergleich mit der gesunden Seite (b) Congenital oder Rekanalisiert

Die drei angefuhrten Arachnoidalzysten bedurfen keiner besonderen Uberlegung PIA wies 1963 erstmals auf Arachnoidalzysten als Ursache infantiler Hemiplegien hin Die angiographischen Veranderungen sind durch den raumfordernden und die Art des Prozesses bedingt eine pranatale Entstehung ist anzunehmen Ob bei den als normal bezeichneten Angiogrammen bzw denjenigen die nur eine Verziehung von Gefässen zur atrophischen Seite hin aufwiesen die Schadigung etwa in der Peripherie der Gefasse gelegen ist und sich somit dem angiographischen Nachweis entzieht muss offen gelassen werden Dass dies der Fall sein kann ist seit den Arbeiten von EICKE MEYER u a bekannt Da in unseren Fallen jedoch ein pathologisch anatomischer Befund fehlt kann eine Aussage hierzu nicht erfolgen

ZUSAMMENFASSUNG

Von 36 ausgewerteten Carotisangiographien bei Patienten mit einseitigen fruhkindlichen Hirnschadigungen zeigten 17 (47 2) Veranderungen an der A cerebri media und deren Äste Bei einem Fall fanden sich zusatzlich noch Auffalligkeiten am Venensystem In der uberwiegenden Mehrzahl war die Schadigung in die Pranatalperiode zu verlegen Diese Befunde entsprechen sowohl der pathologisch anatomischen Erfahrung als auch der anderer Untersucher

SUMMARY

The evaluation of carotid angiography in 36 cases of unilateral cerebral damage in young children revealed changes in the medial cerebral artery or its branches in 17 cases (47 2 %) In one case additional abnormalities in the venous system were evident and in most cases prenatal damage could be assumed The findings correspond well with the views held by morbid pathologists and with the experiences of other investigators



Abb. 2. Hemiatrophia cerebri. Weitgehender Ausfall der Aa. ascendentes frontoparecentral und dünnkalibrige Gefässe der Sylviagruppe (Rekanalisiert?)

u. a.), auch kommen kongenital angelegte Ausfälle, z. T. verbunden mit anderen Missbildungen (MYMIN, NORMANN & URICH, PIA, WOLMAN) vor. Drei der eigenen Fälle wiesen Gefässveränderungen (einmal der Ausfall des Hauptstammes der Sylviagruppe und zweimal dünnkalibrige Gefässe) auf, die im Anschluss an ein schweres Schädelhirntrauma im Frühkindesalter entstanden sind.

Eine weitere Frage ist, welche Gefässe von derartigen Schädigungen betroffen sind. Alle Autoren stimmen darin überein, dass an erster Stelle die A. cerebri med. und ihre Äste stehen, dann folgen mit Abstand die A. carotis int., die A. cerebri post. und ant. (BANKER, DYKEN, DUFFY et coll., GOLDSTEIN & BURGESS, LEFEBVRE et coll., TENG & GOLDENBERG, TÖNNIS, WILLIE u. a.). In unserem Material ist es ausschliesslich die mittlere Hirnarterie und deren Äste, eine Veränderung an einer anderen grossen Hirnarterie kam nicht zur Darstellung. Dabei wurden sowohl komplette Verschlüsse — zweimal imponierte der Ausfall der A. cerebri med. als eine Aplasie —, Teilausfälle und das bekannte Bild der dünnkalibrigen Arterien beobachtet. Bei den letztgenannten Auffälligkeiten (6 Fälle) durfte es sich zum Teil um Rekanalisierungen handeln, wie dies nicht nur experimentell, pathologisch-anatomisch sondern auch angiographisch am Menschen gesichert ist (u. a. BECKER, DECKER, HEUBNER, MAIR, WOLMAN). Das auch in unserem Material praktische Fehlen rein venöser Veränderungen als Ursache der Hemiatrophie ist dadurch zu erklären, dass venöse Verschlüsse und Abflussbehinderungen zwar einmal zu rein halbseitigen Ausfällen führen können (LANG), jedoch ausserordentlich selten sind (PIA). Wir selbst beobachteten nur einmal eine Kombination mit arteriellen Veränderungen bei einem Mädchen, welches im Alter von 10 Jahren plötzlich eine Halbseitenlähmung erlitt.

MYMIN D Carotid thrombosis in childhood *Arch Dis Child* 35 (1960) 515
NORMAN R M and URICH H Dissecting aneurysm of the middle cerebral artery as a cause of acute infantile hemiplegia J Path Bact 73 (1957) 580
PIA H W Die Hemisphärektomie in der Behandlung der cerebralen Kinderlahmung *Dtsch* Z Nervenheilk 181 (1960) 395
— Die operative Behandlung der infantilen Hemiplegie aus prophylaktischer Sicht Prophylaxe u Therapie Bd 2 S 1—2 Wien Brasec 1963
— Neue Wege zur Behandlung der zerebralen Kinderlahmung Tgl Praxis 1 (1960) 439
— Ätiologie und Pathogenese der infantilen Hemiplagie Dtsch Z Nervenheilk 185 (1963) 357
PICAZA J A Cerebral angiography in children J Neurosurg 9 (1952) 235
POSER C M and TAVERAS J M Clinical aspects of cerebral angiography in children Pediatrics 16 (1955) 73
ROSEGAY H and WELCH K Peripheral collateral circulation between cerebral arteries J Neurosurg 11 (1954) 363
SCHWARTZ PH und FINK L Morphologie und Entstehung der geburtstraumatischen Blutungen im Gehirn und Schadel der Neugeborenen Z Kinderheilk 40 (1925) 427
STEVENS H Carotid artery occlusion in childhood Pediatrics 23 (1959) 699
TAVERAS J M and POSER C M Roentgenologic aspects of cerebral angiography in children Amer J Roentgenol 82 (1959) 371
TENG P and GOLDENBERG E D Thrombosis of internal carotid artery in a 5-year-old child A M A J Dis Child 99 (1960) 228
TONNIS W Zit nach LANG
VIGOUROUX R BONDONRESQUES J PIGANIOL G et VIGOUROUX M Valeur respective de la pneumographie de l angiographie et de l elektroencephalographie au cours des encephalopathies infantiles Rev Neurol 90 (1954) 662
WALTER W und BRANDT P Die Angiographie bei den fruhkindlichen Hirnschaden Acta Neurochir 6 (1958) 310
WIESEL J Uber Arterienveranderungen bei kindlichen Infektionskrankheiten Wien klin Wschr 56 (1961) 15
WISOFF H S YOUNKERS Y and ROTHBALLER A Cerebral arterial thrombosis in children Arch Neurol Psychiat 56 (1961) 258
WOLMAN L Cerebral dissecting aneurysms *Brain 82 (1959) 276*
WYLLIE W G Acute infantile hemiplegia Proc roy Soc Med 41 (1948) 459

RÉSUMÉ

Sur angiographies carotidiennes de malades présentant une lésion cérébrale unilatérale datant de la première enfance, 17 (47,2 %) ont montré une altération de l'artère cérébrale moyenne et de ses branches. Dans un cas, il y avait en outre des anomalies du système veineux. Dans la grande majorité des cas la lésion pouvait être rapportée à la période prénatale. Ces résultats concordent aussi bien avec les constatations anatomo-pathologiques qu'avec l'expérience d'autres auteurs.

LITERATUR

ACHSLOGH, J. et SAINTES, M. J.: L'arteriographie normale et pathologique du nourrisson et du jeune enfant. Acta neurol. belg. 61 (1961) 102.

BANKER, S.: Cerebral vascular disease in infancy and childhood. J. Neuropath. exp. Neurol. 20 (1961) 127.

BECKER, H.: Über Hirngefässausschaltungen. Dtsch. Z. Nervenheilk. 161 (1949) 446.

DECKER, K.: Klinische Neuroradiologie. Georg Thieme, Stuttgart 1960.

DUFFY, P., PORTNOY, B., MAURO, J. and WEHRLE, P.: Acute infantile hemiplegia secondary to spontaneous carotid thrombosis. Neurology 7 (1957) 664.

DYKEN, M.: Angiographic study of the middle cerebral artery in chronic infantile hemiplegia. J. Neurol. Neurosurg. Psychiat. 27 (1964) 326.

EICKE, W. J.: Gefässveränderungen bei Meningitis und ihre Bedeutung für die Pathogenese frühkindlicher Hirnschäden. Virchows Arch. path. Anat. 314 (1947) 88.

FIELD: Zit. nach PIA.

FORD, F. R.: Diseases of the nervous system in infancy, childhood and adolescence. 4. Ed. Thomas, Springfield (Ill.) 1960.

GOLDSTEIN, S. L. and BURGESS, J.: Spontaneous thrombosis of the internal carotid artery in a 7 year old child. A. M. A. J. Dis. Child. 95 (1958) 538.

HALLERVORDEN, J.: Das Geburtstrauma als Ursache der Entwicklungshemmung im Kindesalter. Med. Klin. (1937) 1224.

— Entwicklungsstörungen und frühkindliche Erkrankungen des Zentralnervensystems. In: Hdb. Inn. Med. Bd. V/3. J. Springer, Berlin-Göttingen-Heidelberg 1953.

— und MEYER, I. E.: Cerebrale Kinderlähmung. In: Hdb. Spez. pathol. Anat. u. Histol. Bd. 13/4. J. Springer, Berlin-Göttingen-Heidelberg 1956.

HEUBNER, O.: Über zerebrale Kinderlähmung. Med. Blatt 6 (1883) 373.

KUNDRATITZ, K., KLAUSBERGER, E. und ZWEYMÜLLER, E.: Die Bedeutung der Angiographie bei cerebral gestörten Kindern. Mschr. Kinderheilk. 106 (1958) 113.

LANG, W.: Zur Morphologie der infantilen Hemiplegie. Dtsch. Z. Nervenheilk. 185 (1963) 339.

LEFEBVRE, J., LEPINTRE, J., FAURE, C. et PEREZ, J.: Resultats de l'angiographie cérébrale au cours des hémiplegies cérébrales infantiles. Acta radiol. 46 (1956) 456.

MAIR, W. G.: Pathological changes in infantile hemiplegia. Proc. I. Int. Congr. Neuropathol. Rome 1952.

MEYER, I. E.: Über Gefässveränderungen beim fetalen und frühkindlichen Hirnschaden. Arch. Psychiat. u. Z. Neurol. 186 (1951) 437.

— Zur Ätiologie und Pathogenese des fetalen und frühkindlichen Hirnschadens. Z. Kinderheilk. 67 (1949) 123.

— Über die Lokalisation frühkindlicher Hirnschäden in arteriellen Grenzgebieten. Arch. Psychiat. u. Z. Neurol. 190 (1953) 328.

Mynin D Carotid thrombosis in childhood Arch Dis Child 35 (1960) 515

Norman R M and Urich H Dissecting aneurysm of the middle cerebral artery as a cause of acute infantile hemiplegia J Path Bact 73 (1957) 580

Pia H W Die Hemisphärektomie in der Behandlung der cerebralen Kinderlähmung Dtsch Z Nervenheilk 181 (1960) 395

— Die operative Behandlung der infantilen Hemiplegie aus prophylaktischer Sicht. Prophylaxe u Therapie Bd 2 S 1—2 Wien Brasec 1963

— Neue Wege zur Behandlung der zerebralen Kinderlähmung Tgl Praxis 1 (1960) 439

— Ätiologie und Pathogenese der infantilen Hemiplegie Dtsch Z Nervenheilk. 185 (1963) 357

Picaza J A Cerebral angiography in children J Neurosurg 9 (1952) 235

Poser C M and Taveras J M Clinical aspects of cerebral angiography in children Pediatrics 16 (1955) 73

Rosegay H and Welch K Peripheral collateral circulation between cerebral arteries J Neurosurg 11 (1954) 363

Schwartz Ph und Fink L Morphologie und Entstehung der geburtstraumatischen Blutungen im Gehirn und Schädel der Neugeborenen Z Kinderheilk 40 (1925) 427

Stevens H Carotid artery occlusion in childhood Pediatrics 23 (1959) 699

Taveras J M and Poser C M Roentgenologic aspects of cerebral angiography in children Amer J Roentgenol 82 (1959) 371

Teng P and Goldenberg E D Thrombosis of internal carotid artery in a 5-year-old child A M A J Dis Child 99 (1960) 228

Tönnis W Zit nach Lang

Vigouroux R Bondonresques J Paganiol G et Vigouroux M Valeur respective de la pneumographie de l angiographie et de l elektroencephalographie au cours des encephalopathies infantiles Rev Neurol 90 (1954) 662

Walter W und Brandt P Die Angiographie bei den frühkindlichen Hirnschäden Acta Neurochir 6 (1958) 310

Wiesel J Über Arterienveränderungen bei kindlichen Infektionskrankheiten Wien klin Wschr 56 (1961) 15

Wisoff H S Younkers Y and Rothballer A Cerebral arterial thrombosis in children Arch Neurol Psychiat 36 (1961) 258

Wolman L Cerebral dissecting aneurysms Brain 82 (1959) 276

Wyllie W G Acute infantile hemiplegia Proc roy Soc Med 41 (1948) 459

FROM THE DEPARTMENT OF RADIOLOGY, SECTION OF NEURORADIOLOGY (DR C S LODWICK, CHAIRMAN), UNIVERSITY OF MISSOURI MEDICAL CENTER, COLUMBIA, MISSOURI, U S A

ARTERIAL ANASTOMOSES OF THE HUMAN BRAIN

A radiographic-anatomic study

by

GERTRAUD WOLLSCHLAEGER and PAUL B WOLLSCHLAEGER

In 1872 COHNHEIM (4) introduced the term 'end arteries'. HEUBNER (11) injected a colored liquid into the cerebral arteries and observed filling of ligated arteries via very fine collateral vessels. He was convinced of the significance of this meningeal network. His contemporary, DURET (6), also demonstrated the morphologic presence of these structures with colored gelatin solution. BEEVOR (2) defined the areas of distribution of the cerebral arteries. He also confirmed the presence of anastomoses between the major arteries. The functional significance of these meningeal anastomoses has been well demonstrated by VAN DER EECKEN & ADAMS (18) in 1953. They correlated the clinical symptoms with the findings seen in postmortem injected brains using the anatomic terminology of FOIX & LEVY (9). Many authors (5, 8, 12, 13, 14, 15, 16, 17) illustrated the intracerebral collaterals in angiographic studies during life. Many of these authors stress the significance in occlusive disease. FAY (7) in 1925 had already shown anastomoses in injected brain specimens on stereoroentgenograms. He began his study with the original idea of injecting a single artery in order to identify and determine the area of distribution radiographically. However, his injection resulted in almost total

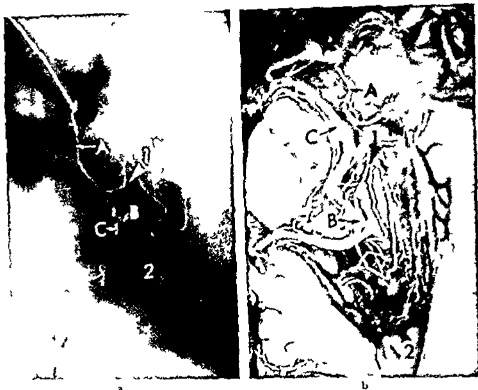


Fig 1 a) Base view of postmortem anterior choroidal artery injection Retrograde filling of posterior cerebral artery (C) via postero-lateral choroidal artery (B) 1 and 2 point to a couple of the numerous anastomoses between the anterior choroidal artery and postero-lateral choroidal artery b) Base view photograph of left brain hemisphere The anterior choroidal artery (A) originates from the internal carotid artery (D) *It has multiple anastomoses with the postero-lateral choroidal* artery (B) especially in the choroid plexus marked 2 The latter artery takes off from the posterior cerebral artery (C)

filling of primarily non injected arteries via the collaterals He did not show the collaterals in the gross specimen

Despite the excellent anatomic and radiographic observation of collaterals there is a lack and need for a correlative study to show the anastomoses on angiograms and corresponding anatomic specimens

The purpose of this paper is to present plainly observed anastomoses or to determine the topographic anatomic site of the anastomoses on the specimen in correlation with the angiogram obtained postmortem

Material and method Seventy brains selected at random were studied between October 1961 and June 1962 The patients age ranged from 23 to 84 years The area of distribution of the selected artery was carefully examined for its



Fig 2 Lateral view into temporal horn and trigonum and main body of lateral ventricle on the specimen The postero lateral choroidal artery (A) crosses the trigonum in the direction of the lateral ventricle and approaches the foramen of Monro (B)

topographic relation to the brain surface and the single artery was then injected with a hand pressure of about 100 mm Hg, using a barium gelatin suspension The injection was immediately terminated when the contrast medium entered the area of distribution of the uninjected artery Roentgenograms of the fresh unfixed brain were taken in the inferior superior (base view) and lateral positions A roentgenogram in the a -p projection was avoided because of the instability of the fresh brain in this position Following angiography of the single injected artery, the brain specimen was usually photographed

All cerebral arteries were then injected and after 14 days fixation the brain was also roentgenographed and photographed for an unrelated special research project Evaluation of the cerebral vasculature of 200 brains

The angiogram of the single injected artery of the fresh brain was subsequently studied and the distribution of this vessel as well as the topographic location of its collaterals were compared with the photographs of the fresh brain If necessary, further correlations with the photographs and roentgenograms of the totally injected brain were undertaken

Results and demonstration of anastomoses

Collaterals were observed in 58 specimens In 12 instances no collaterals could be identified due to the fact that, a) only partial filling of the area of distribution of the single injected artery was achieved because of insufficient in



Fig 3 Base view photograph of hemilateral specimen preparation Postero-medial choroidal artery (A) branches early from posterior cerebral artery (B) and courses around brain stem It enters the third ventricle superiorly and laterally to the pineal gland (C) and continues in an anterior direction on the inferior aspect of the roof of the third ventricle and passes the intraventricular foramen (D) in order to anastomose with the postero-lateral choroidal artery The postero-lateral choroidal artery (E) originates distal to the postero-medial choroidal artery from the posterior cerebral artery enters the temporal horn and disappears in the trigonum after numerous anastomoses with the anterior choroidal artery (F) in the choroidal plexus

jection pressure and b) extravasation of the contrast media obscured the collaterals

In many instances multiple collaterals were noted not only between two *different arterial areas of distribution but also from one area to two different* areas and within one arterial area itself In addition it was seen that a single anastomosis may branch and the neighboring anastomosis may also branch This cross supply was commonly found in the area of the central and post central gyrus However total elucidation of all these cases is to be the subject of a detailed monograph The complexity of the arterial anastomoses will be demonstrated in 5 different cases

In most instances no attempt was made to dissect or elevate the anastomotic branches from the depth of the sulci to the visible surface of the brain, because this would have produced an unreliable picture due to the unfolding of the vessels which would not correspond well to the topographic location of the anastomoses when compared with the postmortem angiogram of the fresh brain

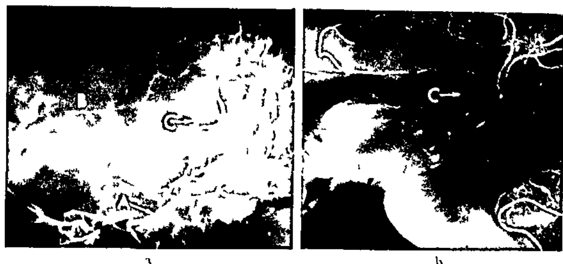


Fig. 4. a) Lateral view of postmortem roentgenograms. The posterior cerebral artery (A) is injected and joins the anterior cerebral artery (B) via the callosal branch (C). b) Radiograph of sagittal brain section (mid line cut). The callosal branch (C) connects the posterior cerebral artery with the anterior cerebral artery.

Numerous injections of the anterior cerebral artery and middle cerebral artery were performed and their anastomoses studied precisely and compared with the work of VAN DER EECKEN & ADAMS 18, and MOUNT & TAVERAS (14). A description of these anastomoses will therefore be omitted.

We were particularly interested in anterior choroidal artery injections. This vessel originated from the internal carotid artery in most cases. Its outer diameter at its origin measured 0.5 mm which corresponds well with the average outer diameter of the anterior choroidal artery registered in a series of 376 measurements by us (19). In this series the maximum diameter of the anterior choroidal artery reached 0.9 mm in a case of interventricular meningioma fed by the anterior choroidal artery. These data are identical with the measurements by CARPENTER et coll. (3), who also described the anatomy and the anastomoses. According to this author, and to ABBIE (1), anastomoses occurred between the anterior choroidal artery and the postero lateral choroidal artery, either rostral to the lateral geniculate body or on the surface of the aforementioned structure or at both sites, in 36 of 45 instances. The inastomoses which were seen on the roentgenograms and dissected specimen of this study were similar to those reported by CARPENTER et coll. (3).

There are immediate anastomoses between the anterior choroidal artery and the postero lateral choroidal artery in the choroid plexus of the lateral portion of the trigonum. In the same region there are multiple small anastomoses. This vessel then takes its course out of the trigonum into the main body of the lateral ventricle and heads towards the foramen of Monro, where it



Fig 5 View into the interhemispheric fissure from posterior The callosal branch (arrow) curves over the splenium of the corpus callosum and links the anterior and posterior cerebral arteries



Fig 6 Postmortem roentgenogram lateral view The superior cerebellar artery (A) is injected and anastomoses with the inferior posterior cerebellar artery (B) at 1 and 2 Note relationship of the inferior posterior cerebellar artery (B) to the roof of the fourth ventricle

meets with the postero medial choroidal artery The latter originates separately either from the proximal posterior cerebral artery or the distal basilar artery From there its pathway can be observed around the brain stem approaching the roof of the third ventricle superiorly and slightly laterally to the pineal gland Further on it enters the foramen of Monro with very fine branches which anastomose with the postero lateral choroidal artery in the lateral ventricle This would indicate that all choroidal arteries should be considered as a functional unit

During the injection of posterior cerebral arteries we noticed filling of a fine callosal branch of the posterior cerebral artery which combines with the pericallosal artery This anastomosis is anatomically located in the midline while the vessel curves over the splenium of the corpus callosum Another interesting connection occurs between the parietal branch of the posterior cerebral artery and the cuneal branch of the anterior cerebral artery The cuneal branch of the anterior cerebral artery on the other hand joins the ascending parietal branch of the middle cerebral artery and produces retrograde filling of the middle cerebral artery distribution The topographic anatomic location of this anastomosis is recognized on the precuneus and cuneus, at the medial surface of the hemisphere



a b

Fig 7 a) Base view photograph of left cerebellum after total injection The anastomoses are seen at the great horizontal fissure at 1 and 2 b) Lateral view of cerebellum The lateral branch of the superior cerebellar artery (A) anastomoses with the inferior posterior cerebellar artery at 1

We also achieved anastomosis between the posterior temporal branch of the posterior cerebral artery and the posterior temporal branch of the middle cerebral artery This anastomosis is located in the parieto occipital sulcus

Single injection into cerebellar arteries likewise produced very informative anastomoses, a few of which are illustrated

Branches of the posterior cerebellar artery frequently cause filling of twigs of the anterior inferior cerebellar or superior cerebellar arteries The inferior posterior cerebellar artery winds around the medulla oblongata in a posterior medial direction, so that a loop is formed with the convexity in the apex of the rhomboidal fossa This loop has a close relation to the roof of the fourth ventricle In this region, anastomoses with the inferior posterior cerebellar artery of the opposite side are commonly observed The vessel transcends in a posterior inferior direction parallel to the anterior inferior surface of the cerebellum, and crosses over the medial portion of the tonsil On the inferior lateral border of the tonsil, the vessel divides into a medial and lateral branch The lateral branch passes over the biventer and its multiple branches cross the great horizontal fissure to the superior surface of the cerebellum to anastomose with the lateral branches of the superior cerebellar artery The medial branch of the inferior posterior cerebellar artery often combines with the medial branch of the superior cerebellar artery on the medial portion of the posterior superior lobule

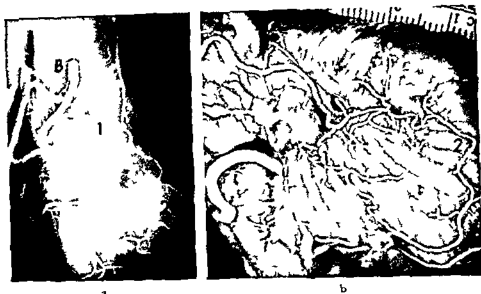


Fig 8 a) Postmortem roentgenogram base view of cerebellum The inferior posterior cerebellar artery (B) is injected and shows anastomoses with the superior cerebellar artery (A) at 1 and 2 b) Photograph of brain specimen in (a) The anastomoses 1 and 2 are visible without being elevated from the fissure

Discussion

The postmortem injection of barium gelatin suspension was used by many authors in the past to demonstrate arterial anastomoses Usually however the anastomotic channels were analyzed only on anatomic specimens or only on roentgenograms of the specimens Of equal importance are photographs of the surface of the injected brain to verify the topographic region of the radiographically recognized anastomoses Surface photographs make the dissection and elevation of the anastomoses and tributaries unnecessary in most instances Any dissection and elevation of vessels from the depths of the sulci will result in an unfolding which will demonstrate the total length of the vessel but this will exceed by 2 to 4 times the length of the previously occupied brain surface Any artificial placement of the unfolded vessels will produce an unrealistic impression However in some instances a dissection is certainly necessary The use of the freshly injected specimen for radiographic study has the great advantage that the same brain can be used for a subsequent study, if the final total injection is done prior to coagulation of the barium gelatin suspension However a slight disadvantage of using fresh brains is the instability this was overcome by wrapping the brain in gauze and by selecting

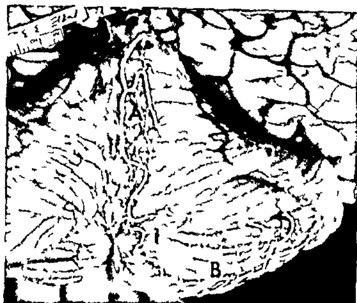


Fig 9 Brain specimen rostral view of cerebellum The dorso medial branch of the superior cerebellar artery (A) anastomoses at the great horizontal fissure (1) with the posterior inferior cerebellar artery (B)

the lateral and infero superior position (base view) for the roentgenography The injection of a single artery may not always result in filling of all possible anastomoses from the injected area of distribution to another area When this happens it is necessary to repeat the injection of the same artery in a different brain

Collaterals were seen on the roentgenograms of all 58 brains A very striking finding was the frequent presence of double anastomotic channels in the prerolandic, rolandic and postrolandic regions An evaluation of this observation and the anatomic variation of the tributaries which feed the arterial anastomoses in human brain over this region will be included in the monograph

Our special interest was directed to the anterior and posterior choroidal arteries and their anastomoses Most authors agree that the anastomoses between the postero lateral choroidal artery and the anterior choroidal artery are located in the temporal horn and in the choroid plexus of the trigonum extending into the posterior portion of the body of the lateral ventricle They also agree that the postero medial choroidal artery arises from the posterior cerebral artery or basilar artery proximal to the origin of the postero lateral choroidal artery Through dissection of 9 specimens for demonstration of the topographic site of the anastomoses, it was noted in most instances that the postero medial choroidal artery originates superiorly or lateral superiorly from the posterior cerebral artery and then turns medial to the posterior cerebral artery, trails around the brain stem, and enters laterally and superiorly

to the pineal body and laterally and inferiorly to the internal cerebral vein of the third ventricle Usually, it was easy to follow this artery to the foramen of Monro According to GALLOWAY & GREITZ (10) there is no connection between the anterior choroidal artery and the postero medial choroidal artery However, we observed and demonstrated its filling from the anterior choroidal artery by way of the postero lateral choroidal artery We agree with these authors that the postero lateral choroidal artery does not come to the sagittal midline of the brain, as does the postero medial choroidal artery The clinical significance of the anastomoses between the anterior choroidal and posterior choroidal arteries is important in the presence of tumors of the choroid plexus intraventricular meningiomas, and in the presence of A V malformations The anastomoses from the posterior cerebral artery to the middle cerebral artery and to the anterior cerebral artery are well known Variations of the topographic site were observed The anastomoses on the cerebellum have been well described by KRAYENBUHL & YASARGIL (12) Concerning the anastomoses over the cerebellum in one instance we noticed a connection between the left inferior posterior cerebellar artery and the left superior cerebellar artery and the right posterior cerebral artery Such anastomoses complicate the localization of A V malformations in these areas of distribution The space available here does not allow a complete description of the enormous variety of anastomoses on the cerebellum

Acknowledgements

This work represents a part of a study performed as Special Fellows of Neuroradiology NIH Traineeship Grant No 2F11 NB 998 02 NIH Traineeship Grant No 2F11 NB 878-03 and Grant No B-2471 (CL) at Albert Einstein College of Medicine New York 61 N Y, U S A

SUMMARY

Arterial anastomoses of the human brain were demonstrated on post mortem angiograms with correlation of the topographic anatomical region on brain specimens Special attention was directed to the anterior choroidal artery and its anastomoses with the posterior choroidal arteries

ZUSAMMENFASSUNG

Arterielle Anastomosen des menschlichen Gehirns wurden mittels postmortaler Angiographie dargestellt und gleichzeitig auf die topographisch anatomische Lagebeziehung am Gehirn hingewiesen Dabei wurde der Arteria chorioidalis anterior nebst ihrer Anastomosen mit der Arteria chorioidalis posterior besondere Beachtung gezollt

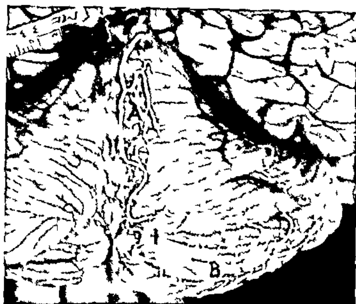


Fig 9 Brain specimen rostral view of cerebellum The dorso medial branch of the superior cerebellar artery (A) anastomoses at the great horizontal fissure (1) with the posterior inferior cerebellar artery (B)

the lateral and infero superior position (base-view) for the roentgenography The injection of a single artery may not always result in filling of all possible anastomoses from the injected area of distribution to another area When this happens it is necessary to repeat the injection of the same artery in a different brain

Collaterals were seen on the roentgenograms of all 58 brains A very striking finding was the frequent presence of double anastomotic channels in the prerolandic, rolandic and postrolandic regions An evaluation of this observation and the anatomic variation of the tributaries which feed the arterial anastomoses in human brain over this region will be included in the monograph

Our special interest was directed to the anterior and posterior choroidal arteries and their anastomoses Most authors agree that the anastomoses between the postero lateral choroidal artery and the anterior choroidal artery are located in the temporal horn and in the choroid plexus of the trigonum extending into the posterior portion of the body of the lateral ventricle They also agree that the postero medial choroidal artery arises from the posterior cerebral artery or basilar artery proximal to the origin of the postero lateral choroidal artery Through dissection of 9 specimens for demonstration of the topographic site of the anastomoses, it was noted in most instances that the postero medial choroidal artery originates superiorly or lateral superiorly from the posterior cerebral artery and then turns medial to the posterior cerebral artery, trails around the brain stem, and enters laterally and superiorly

to the pineal body and laterally and inferiorly to the internal cerebral vein of the third ventricle Usually, it was easy to follow this artery to the *foramen* of Monro According to GALLOWAY & GREITZ (10) there is no connection between the anterior choroidal artery and the postero medial choroidal artery However, we observed and demonstrated its filling from the anterior choroidal artery by way of the postero lateral choroidal artery We agree with these authors that the postero lateral choroidal artery does not come to the sagittal midline of the brain as does the postero medial choroidal artery The clinical significance of the anastomoses between the anterior choroidal and posterior choroidal arteries is important in the presence of tumors of the choroid plexus intraventricular meningiomas and in the presence of A V malformations The anastomoses from the posterior cerebral artery to the middle cerebral artery and to the anterior cerebral artery are well known Variations of the topographic site were observed The anastomoses on the cerebellum have been well described by KRAYENBUHL & YASARGIL (12) Concerning the anastomoses over the cerebellum, in one instance we noticed a connection between the left inferior posterior cerebellar artery and the left superior cerebellar artery and the right posterior cerebral artery Such anastomoses complicate the localization of A V malformations in these areas of distribution The space available here does not allow a complete description of the enormous variety of anastomoses on the cerebellum

Acknowledgements

This work represents a part of a study performed as Special Fellows of Neuroradiology NIH Traineeship Grant No 2F11 NB 938-02 NIH Traineeship Grant No 2F11 NB 878-03 and Grant No B-2471 (CL) at Albert Einstein College of Medicine New York 61 N Y U S A

SUMMARY

Arterial anastomoses of the human brain were demonstrated on post mortem angiograms with correlation of the topographic anatomical region on brain specimens Special attention was directed to the anterior choroidal artery and its anastomoses with the posterior choroidal arteries

ZUSAMMENFASSUNG

Arterielle Anastomosen des menschlichen Gehirns wurden mittels postmortaler Angiographie dargestellt und gleichzeitig auf die *topographisch anatomische Lagebeziehung* am Gehirn hingewiesen Dabei wurde der Arteria chorioidalis anterior nebst ihrer Anastomosen mit der Arteria chorioidalis posterior besondere Beachtung gezollt

RÉSUMÉ

Les anastomoses artérielles du cerveau humain ont été étudiées par angiographie post mortem confrontée avec l étude topographique de pièces d autopsie L auteur a étudié spécialement les anastomoses de l artère choroidienne antérieure avec les artères choroidiennes *postérieures*

REFERENCES

1 ABBIE A A The blood supply of the lateral geniculate body with a note on the morphology of the choroidal arteries *J Anat* 67 (1933) 491

2 BEEVOR C E The cerebral arterial supply Brain 30 (1907) 403

3 CARPENTER M B NOBACK C R and MOSS M L The anterior choroidal artery Arch Neurol Psychiat 71 (1954), 714

4 COHNHEIM J Untersuchungen uber die embolischen Processe August Hirschwald Berlin 1872 Cited by TONNIS und SCHIEFER

5 DECKER K und HOLZER L Gefassverschlusse im Carotis und Vertebralisangiogramm Fortschr Rontgenstr 80 (1954) 565

6 DURET H Recherches anatomiques sur la circulation de l encéphale Arch physiol norm et path Second series 1 (1874) 60 316

7 FAY T The cerebral vasculature Preliminary report of study by means of roentgen ray J Amer med Ass 84 (1925) 1727

8 FEIRING E H and SUSSMAN B J Spontaneous occlusion of the middle cerebral artery Neurology 6 (1956) 529

9 FOIX C and LEVY M Ramollissement Sylvius Rev neurol 21 (1927) 51

10 GALLOWAY J R and GREITZ T The medial and lateral choroid arteries An anatomic and roentgenographic study Acta radiol 53 (1960) 353

11 HEUBNER O Zur Topographie der Ernahrungsgebiete der einzelnen Hirnarterien Zbl med Wiss 10 (1872) 817

12 KRAYENBUHL H und YASARGIL M G Die vascularen Erkrankungen im Gebiete der Arteria vertebralis und Arteria basialis Georg Thieme Verlag Stuttgart 1957

13 MOUNT L A and TAVERAS J M A study of the collateral circulation of the brain following ligation of the internal carotid artery Trans Amer neurol Ass 78 (1953) 47

14 — — Arteriographic demonstration of the collateral circulation of the cerebral hemispheres A M A Arch Neurol Psychiat 78 (1957) 235

15 ROSEGAY H and WELCH K Peripheral collateral circulation between cerebral arteries A demonstration by angiography of the meningeal arterial anastomoses J Neurosurg 11 (1954) 363

16 TATELMAN M Pathways of cerebral collateral circulation Radiology 75 (1960) 349

17 TONNIS W und SCHIEFER W Zirkulationsstorungen des Gehirns im Serienangiogramm pgs 46 und 139 Springer Verlag Berlin 1959

18 VAN DER EECKEN M and ADAMS R D The anatomy and functional significance of the meningeal arterial anastomoses of the human brain J Neuropath exp Neurol 12 (1953) 132

19 WOLLSCHLAEGER G and WOLLSCHLAEGER P B The anterior choroidal artery To be published Presented at the meeting of the Neuroradiological Society of North Amer Atlantic City U S A June 1965

FROM THE DEPAPTMENT OF RADIOLOGY SECTION OF NEURORADIOLOGY (DR G S LODWICK CHAIRMAN) UNIVERSITY OF MISSOURI MEDICAL CENTER COLUMBIA, MISSOURI U S A

ANTERIOR CEREBRAL/INTERNAL CAROTID ARTERY AND MIDDLE CEREBRAL/INTERNAL CAROTID ARTERY RATIOS

by

PAUL B WOLLSCHLAEGER and GERTRAUD WOLLSCHLAEGER

During the interpretation of carotid angiograms the problem of whether one is dealing with hypoplastic spastic or arteriosclerotic arteries often arises and it is difficult to define what *should be considered an average diameter* for a vessel of the circle of Willis as stated by KIRGIS et coll With respect to the first category the pathologist generally defines hypoplasia as a congenital defective formation in which there is incomplete development of an organ or a part ALPERS and his co authors remarked that stringlike vessels with a diameter of 1 mm are hypoplastic but functional

The evaluation of an artery from the *standpoint of the diameter of the* lumen may be done by measuring the involved vessel PALLIE & SAMARASINHE have contributed interesting and valuable information from studies of 12 brain specimens On the other hand one might prefer correlations of branching arteries like TURNER who reported the results of arterial radius measurements of the vertebral arteries and basilar artery

The purpose of this paper is to arrive at measurements of single arteries

RÉSUMÉ

Les anastomoses arterielles du cerveau humain ont été étudiées par angiographie post mortem confrontée avec l étude topographique de pieces d autopsie L auteur a étudié spécialement les anastomoses de l artère choroidienne antérieure avec les artères choroidiennes postérieures

REFERENCES

1 Abbie A A The blood supply of the lateral geniculate body with a note on the morphology of the choroidal arteries J Anat 67 (1933) 491

2 Beevor C L The cerebral arterial supply Brain 30 (1907), 403

3 Carpenter M B, Noback C R and Moss M L The anterior choroidal artery Arch Neurol Psychiat 71 (1954) 714

4 Cohnheim J Untersuchungen uber die embolischen Processe August Hirschwald Berlin 1872 Cited by Tonnis und Schiefer

5 Decker K und Holzer E Gefassverschlusse im Carotis und Vertebralisangiogramm Fortschr Rontgenstr 80 (1954) 565

6 Duret H Recherches anatomiques sur la circulation de l encéphale Arch physiol norm et path Second series 1 (1874) 60 316

7 Fay T The cerebral vasculature Preliminary report of study by means of roentgen ray J Amer med Ass 84 (1925) 1727

8 Fleming E H and Sussman B J Spontaneous occlusion of the middle cerebral artery Neurology 6 (1956) 529

9 Foix C and Levy M Ramollissement Sylvius Rev neurol 21 (1927) 51

10 Galloway J R and Greitz T The medial and lateral choroid arteries An anatomic and roentgenographic study Acta radiol 53 (1960) 353

11 Heubner O Zur Topographie der Ernahrungsgebiete der einzelnen Hirnarterien Zbl med Wiss 10 (1872) 817

12 Krayenbuhl H und Yasargil M G Die vascularen Erkrankungen im Gebiete der Arteria vertebralis und Arteria basialis Georg Thieme Verlag Stuttgart 1957

13 Mount L A and Taveras J M A study of the collateral circulation of the brain following ligation of the internal carotid artery Trans Amer neurol Ass 78 (1953) 47

14 — — Arteriographic demonstration of the collateral circulation of the cerebral hemispheres A M A Arch Neurol Psychiat 78 (1957) 235

15 Rosegay H and Welch K Peripheral collateral circulation between cerebral arteries A demonstration by angiography of the meningeal arterial anastomoses J Neurosurg 11 (1954) 363

16 Tatelman M Pathways of cerebral collateral circulation Radiology 75 (1960) 349

17 Tonnis W und Schiefer W Zirkulationsstorungen des Gehirns im Serienangiogramm pgs 46 und 139 Springer Verlag Berlin 1959

18 Van der Eecken M and Adams R D The anatomy and functional significance of the meningeal arterial anastomoses of the human brain J Neuropath exp Neurol 12 (1953) 132

19 Wollschlaeger G and Wollschlaeger P B The anterior choroidal artery To be published Presented at the meeting of the Neuroradiological Society of North Amer Atlantic City U S A June 1965

ROM THE DEPARTMENT OF RADIOLOGY, SECTION OF NEURORADIOLOGY (DR G S ODWICK CHAIRMAN) UNIVERSITY OF MISSOURI MEDICAL CENTER COLUMBIA, MISSOURI U S A

ANTERIOR CEREBRAL/INTERNAL CAROTID ARTERY AND MIDDLE CEREBRAL/INTERNAL CAROTID ARTERY RATIOS

by

PAUL B WOLLSCHLAEGER and GERTRAUD WOLLSCHLAEGER

During the interpretation of carotid angiograms the problem of whether one is dealing with hypoplastic spastic or arteriosclerotic arteries often arises and it is difficult to define what should be considered an average diameter for a vessel of the circle of Willis as stated by KIRGIS et coll With respect to the first category the pathologist generally defines hypoplasia as a congenital defective formation in which there is incomplete development of an organ or a part ALPERS and his co authors remarked that stringlike vessels with a diameter of 1 mm are hypoplastic but functional

The evaluation of an artery from the standpoint of the diameter of the lumen may be done by measuring the involved vessel PALLIE & SAMARASINHE have contributed interesting and valuable information from studies of 12 brain specimens On the other hand one might prefer correlations of branching arteries like TURNER who reported the results of arterial radius measurements of the vertebral arteries and basilar artery

The purpose of this paper is to arrive at measurements of single arteries

SCHEME OF MEASUREMENTS

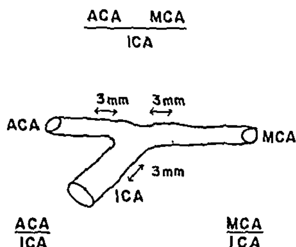


Fig 1 Diagrammatic representation of method of measurement

and also to establish ratios between the branching vessels for evaluation of the presence of a hypoplastic artery

A total of 1 050 *measurements* of the outside diameter of the anterior cerebral artery (ACA), middle cerebral artery (MCA), and internal carotid artery (ICA) were made on 175 unselected brain specimens, which had been injected with a barium gelatin suspension immediately after removal After ten days of fixation the diameters were read at points 3 mm proximal and 3 mm distal to the division of the internal carotid artery into the anterior cerebral and middle cerebral arteries (*Figs 1 and 2*) Similar measurements were made in the arterial phase of the half axial a p projection of 124 angiograms

The results were as follows *In the angiographic* studies we were measuring the intraluminal diameters, which amounted in average (130 angiograms) to 2 03 mm for ACA, 2 87 mm for MCA and 3 88 mm for ICA, as compared with the postmortem diameters (352), which were 1 7 mm for ACA, 2 5 mm for MCA and *3 7 mm for* ICA The differences of angiographic versus post mortem data were 0 33 mm for ACA (16 %), 0 37 mm for MCA (13 %) and 0 18 mm for ICA (4 6 %)

From the measurements listed previously, the average ratio was obtained by calculation on the postmortem and in vivo studies as follows

ACA/ICA postmortem 0 459, in vivo 0 5241, difference 0 0651

MCA/ICA postmortem 0 675, in vivo 0 7395, difference 0 0615

$\frac{ACA + MCA}{ICA}$ postmortem 1 135, in vivo 1 2637, difference 0 1287



Fig 2 The normal trifurcation Sections of base view of postmortem angiogram (top) of base view of total brain specimen after injection (centre) and of circle of Willis of same specimen (bottom) Site of measurements indicated by black lines on bottom section A = first portion of anterior cerebral artery M = first part of middle cerebral artery ICA = internal carotid artery

The 10—20 % value increase of the in vivo measurements can be explained by roentgenographic magnification and also by the fact that we were dealing with two different populations The single postmortem figures for ACA were compared with the macroscopic brain description of the neuropathologic service respective to hypoplasia of this vessel There we learned that anterior cerebral arteries with diameters of about one millimeter or less have been called hypoplastic This corresponds with the figures mentioned in the literature From comparison of the ACA diameter in our angiographic series with independent reports of the neuropathologic department on the same diseased patients we concluded that an angiographic ACA diameter of 1 2 mm or less may be considered hypoplastic Therefore our postmortem single diameter value concerning hypoplasia of the anterior cerebral artery can be applied in angiography



Fig. 3. a) Right carotid angiogram with compression of contralateral internal carotid artery: half axial a.-p. view. Filling of right and left anterior cerebral arteries. The right is hypoplastic (arrow). b) Base view of brain specimen from same patient. Right anterior cerebral artery is hypoplastic (arrow).

The average postmortem ACA/ICA ratio was 0.45, but decreased to 0.28, when there was evidence of hypoplasia, in 31 instances. In 10 angiographic cases with a hypoplastic anterior cerebral artery the ACA/ICA ratio showed only minimal variations and was about 0.29. This proves, likewise, that our postmortem ratio values can be used in in vivo evaluation of arterial hypoplasia.

We are aware of the risk that figures arrived at from postmortem material may not be entirely reliable. We have studied a patient at in vivo angiography and at necropsy (Fig. 3). Both in vivo and postmortem ACA diameters measured 1 mm. The in vivo ACA/ICA ratio was 0.28 and the postmortem ACA/ICA ratio 0.25. The individual measurements as well as the ratios were just about equivalent.

In cases of arteriosclerosis, our figures vary markedly from one brain specimen to another (Fig. 4). It is known that the diameter alters within short distances and that the measurements at a given point may meet normal arterial width. For this reason single data and ratios would fall within normal ranges. It might also be necessary to consider the factor that in vivo and postmortem data in arteriosclerosis represent lower and upper range extremes for one particular case, which is explained by the increasing wall thickness due to irregular atheromatous plaques.



Fig 4 a) Angiogram taken w th half axial a p projection Marked beating of intracranial arteries This appearance s identical with severe arteriosclerot c changes b) Base v ew of brain spec men f om same pat ent Diameters of vessels variable due to atheromatous plaques (arrow)

The values obtained for single diameters and ratios could not be employed in cases of arterial spasm One reason is the limited number of cases with true and proven occurrence of spasm ECKER & RIEMENSCHNEIDER have discussed the reliability of angiographic evidence of spasm in the internal carotid arteries and their main branches and have listed an interesting grading of arterial spasm They also emphasized the fact that it is necessary to see a vessel in two projections at different series and times Other authors (DECKER HERMANN HUBER KRAYENBUHL) were able to verify the presence of spasm so called post traumatic arterial diameter fluctuations by follow up angiography of their patients However in many cases it is impossible to re examine patients and therefore other means of definition must be found We shall certainly pursue this field further Second it is quite possible in this category that one measured diameter and its calculated ratio at a given point of the branching artery is not sufficient since spasm frequently exceeds one segment or more of an artery and often involves two branching vessels Additional measurements on specified distances may be necessary and a subtraction factor perhaps worked out in order to differentiate arterial spasm from hypoplastic vessels

Acknowledgement

This work represents a part of a study performed as special fellows of neuroradiology, NIH Traineeship Grant 2F11 NB 998 02 and NIH Traineeship Grant 2F11 NB 8/8-03 at Albert Einstein College of Medicine, New York, U S A

SUMMARY

Average diameters of the anterior cerebral artery middle cerebral artery and internal carotid artery close to the bifurcation of the internal carotid artery and their ratios were established, and an attempt was made to apply the obtained data, especially in cases of hypoplasia, and also though to a limited extent, in cases of spasm and arteriosclerosis The ratios arrived at postmortem can be applied practically in angiographic studies in vivo

ZUSAMMENFASSUNG

Die Durchmesser der Arterien zerebralis anterior, media und carotis interna dicht bei der Verzweigung der Arteria carotis interna wurden notiert und deren Verhaltniswerte auf gestellt In einer Versuchsreihe wurden die erarbeiteten Werte in Fallen von arterieller Hypoplasie und im begrenzten Umfange in Fallen mit Gefassspasmus und Arteriosklerosis angewandt Die an Gehirnpraparaten erhaltenen Verhaltniswerte konnen auf die zerebrale Angiographie in vivo ubertragen werden

RÉSUMÉ

L auteur a mesuré le diamètre moyen des artères cérébrale antérieure cérébrale moyenne et carotide interne et il a calculé leur rapport et a essayé d appliquer ces resultats aux cas d hypoplasie et aussi dans une certaine mesure a des cas de spasme et d artériosclerose On peut pratiquement appliquer aux études angiographiques in vivo les rapports établis post mortem

REFERENCES

ALPERS B J BERRY R G and PADDISON R M Anatomical studies of the circle of Willis in normal brain A M A Arch Neurol Psychiat 81 (1959) 409

DECKER K Der Spasm der Arteria carotis interna Acta radiol 46 (1956) 351

ECKER A and RIEMENSCHNEIDER P A Arteriographic evidence of spasm in cerebral vascular disorder Neurology 3 (1953) 495

HERMANN E Die Deutung der Einengung des Supraclinoidalen Syphonabschnittes der Arteria Carotis Interna im Arteriogramm Dtsch Z Nervenheilk 183 (1961) 99

HUBER P Posttraumatische Kaliberschwankungen der Hirngefasse im Angiogramm Fort schr Rontgenstr 98 (1963) 292

KIRGIS H D LLEWELLYN R C and PEEBLES E M Functional trifurcation of the internal carotid artery and its potential clinical significance J Neurosurg 17 (1960) 1062

KRAYENBUHL H Beitrag zur Frage des Cerebralen Angiographischen Insultes Schweiz med Wschr 90 (1960) 961

PALLIE W and SAMARASINHE D D A study in the quantification of the circle of Willis Brain 85 (1962) 569

TURNER R A comparison of theoretical measurements with observed angles between the vertebral arteries and their function to form the basilar artery Anat Record 129 (1957) 243

ZÜLCH K J Gibt es Spasm der Hirngefasse? Medizinische 14 (1959) 622

M THE DEPARTMENTS OF RADIOLOGY (DIAGNOSTIC DIVISION) AND MEDICINE
VISION OF NEUROLOGY) STANFORD UNIVERSITY SCHOOL OF MEDICINE, PALO
ALTO CALIF, USA

CEREBRAL EMBOLI COMPLICATING CEREBRAL ANGIOGRAPHY

by

LESLIE M ZATZ and ANTHONY M IANNONE

A wide variety of complications has been reported following cerebral ngiography, ranging from minimal neurologic deficits to hemiplegia, con ulsions and death In the past such untoward sequelae have usually been ttributed to the hyperosmotic iodinated contrast agents employed In recent ears the contrast agents originally employed have been discarded and re placed by agents with a considerably larger margin of safety Any evidence that known complications in man are produced by factors other than the contrast agents and are preventable would be of importance in decreasing the risk of this procedure This paper presents evidence that emboli may be the responsible agent in certain complications that embolic accidents may be directly related to technical factors and that preventive measures may de crease the incidence of such complications

Diagnostic criteria

The recognition of an embolic complication depends on the identification of an intracerebral occlusion which occurred during the procedure An intra cerebral arterial occlusion is identified by (1) the absence of vessels in an area

usually supplied by a particular vessel, (2) the presence of an abrupt termination of a vessel prior to its normal arborization, or (3) the retrograde flow of contrast material into an occluded area from leptomeningeal collaterals (10, 18, 19). While an occlusion of the middle cerebral artery may be easily recognized by its lack of filling, an absence of filling of one of its branches may not be observed because of overlap of other branches. In such an instance, criteria (2) and (3) are the most important. The filling of the occluded vessel and of the collateral vessels is slower than that of normal arteries. These vessels may not be seen until the small vessel or venous phase of the study.

To demonstrate small vessel occlusions, serial angiography covering seven or eight seconds, at least in the lateral projection, is a necessity. This usually consists of two films per second for three seconds followed by one film per second for an additional four seconds. Stereoscopic lateral films are obtained by alternate exposure with one of a pair of roentgen tubes. This has been of great help in separating superimposed vessels and in tracing collateral vessels into an area of occlusion.

The occlusion can be deduced to be embolic under certain circumstances. The most reliable evidence is the presence on one film of a vessel which is then found to be occluded on a second film a few minutes later. In other cases, the actual process of occlusion may be demonstrated on successive films in the same angiographic series. Failure to demonstrate a vessel at one examination during which a neurologic complication developed is also suggestive if the vessel was present on films from a previous angiography during the same illness. The finding of multiple small vessel occlusions in different vessels at the onset of a complication most likely indicates multiple emboli. When a repeat angiography shows the site of a previously identified obstruction to be smooth and regular after lysis of the occlusion, the original lesion was more likely embolic than thrombotic.

Case reports

Case 1. A 49 year old right handed female with a history of a previously resected bronchiolar carcinoma was examined because of increased intracranial pressure and major motor seizures. The ultimate diagnosis proved to be carcinomatous infiltration of the meninges. During her evaluation percutaneous left carotid angiography was done. A halfaxial series was exposed first followed by a lateral series. Immediately upon completion of the examination the patient was noted to be dysphasic and to have a right hemiparesis. The arteriogram revealed that an occlusion of a branch of the middle cerebral artery to the region of the motor cortex had occurred between the first and second examinations probably due to an embolus (Fig. 1). Within 3 hours the neurologic defects had improved considerably and by 24 hours had completely disappeared.

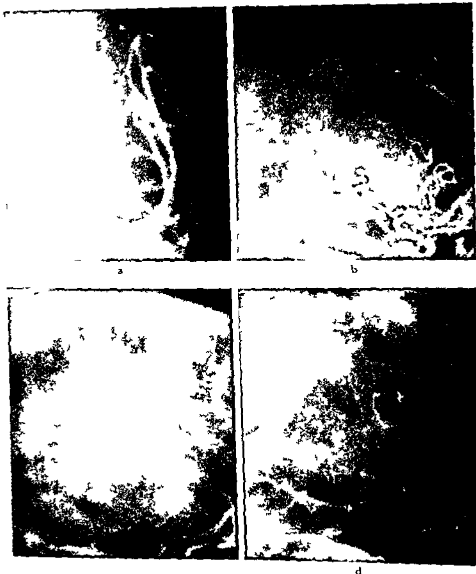


Fig 1 Case 1 a) Arter al phase n half ax al p oject on from fi st injection Six branches of middle cer bral a tery run t ans e ely n the Syl an h sure no evidence of collateral vessels in subsequent f lms of the series b) c) and d) Sel cted arly mid and late arterial films from lateral ser es following the half axial study In (b) no m ddle cerebral branches in f ontoparietal area a mall s lp essel may be dentified by its character st c convoluted course Only four branches of m ddle cereb al artery em rg from Sylv an fissure n co trast to the six branches noted in the fi st ser es Th ind cated vascular occlusion between the first and second series In (c) several art al branches beg n to fill n et ograde fa h on nto the avascular area and in (d) progress f ther toward Sylvian fissure The retrograde fill ng of the occluded branches indicates collateral an stomoses

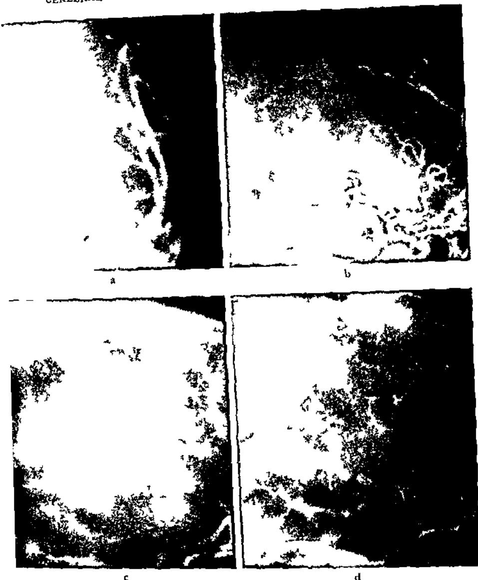
usually supplied by a particular vessel, (2) the presence of an abrupt termination of a vessel prior to its normal arborization, or (3) the retrograde flow of contrast material into an occluded area from leptomeningeal collaterals (10, 18, 19) While an occlusion of the middle cerebral artery may be easily recognized by its lack of filling, an absence of filling of one of its branches may *not* be observed because of overlap of other branches In such an instance, criteria (2) and (3) are the most important The filling of the occluded vessel and of the collateral vessels is slower than that of normal arteries These vessels may not be seen until the small vessel or venous phase of the study

To demonstrate small vessel occlusions, serial angiography covering seven or eight seconds, at least in the lateral projection, is a necessity This usually consists of two films per second for three seconds followed by one film per second for an additional four seconds Stereoscopic lateral films are obtained by alternate exposure with one of a pair of roentgen tubes This has been of great help in separating superimposed vessels and in tracing collateral vessels into an area of occlusion

The occlusion can be deduced to be embolic under certain circumstances The most reliable evidence is the presence on one film of a vessel which is then found to be occluded on a second film a few minutes later In other cases, the actual process of occlusion may be demonstrated on successive films in the same angiographic series Failure to demonstrate a vessel at one examination during which a neurologic complication developed is also suggestive if the vessel was present on films from a previous angiography during the same illness The finding of multiple small vessel occlusions in different vessels at the onset of a complication most likely indicates multiple emboli When a repeat angiography shows the site of a previously identified obstruction to be smooth and regular after lysis of the occlusion, the original lesion was more likely embolic than thrombotic

Case reports

Case 1 A 49 year old right handed female with a history of a previously resected bronchiolar carcinoma was examined because of increased intracranial pressure and major motor seizures The ultimate diagnosis is proved to be carcinomatous infiltration of the meninges During her evaluation percutaneous left carotid angiography was done A halfaxial series was exposed first followed by a lateral series Immediately upon completion of the examination the patient was noted to be dysphasic and to have a right hemiparesis The arteriogram revealed that an occlusion of a branch of the middle cerebral artery to the region of the motor cortex had occurred between the first and second examinations probably due to an embolus (Fig 1) Within 3 hours the neurologic defects had improved considerably and by 24 hours had completely disappeared



'g 1 Case 1 a) Arterial phase in half axial project on from first injection Six branches of middle ereb al artery run trans ersely in the Sylvian fissure no e idence of collateral vessels in sub e juent films of the s es b) c) nd d) Selected early mid and late a terial films from lateral eries f llow ng the half ax al study In (b) no m ddle cerebral branches in frontopar etal area i small sc lp ess l may be identified by its character stic cor voluted course Only fou branches of m ddl cereb l a te y emerge from Sylv n fissure in contrast to the six branches noted in he first eries This nd cated v s ular occlusion between the h st and second series In (c) several te l branches b gin to fill in retrograde fash on into the avas ular a ea and in (d) progress urth r towa d Syl an fissure The retrograde fill ng of the occluded branches ind cates collateral an tomoses.

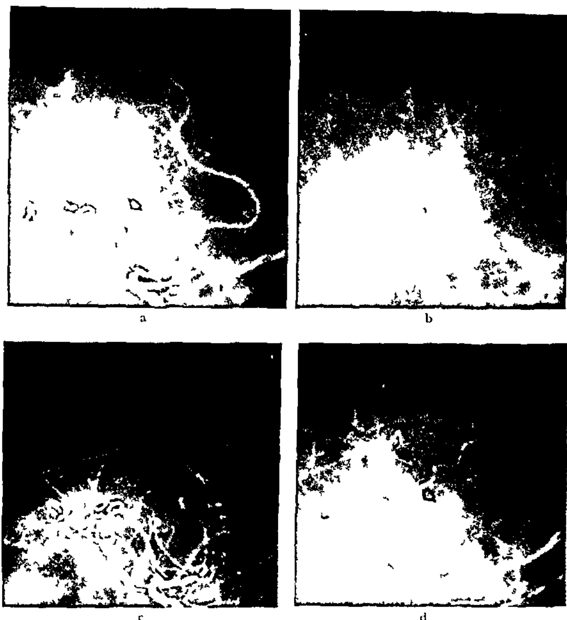


Fig 2 Case 2 (a) and (b) Early arterial and early venous phases from first lateral series Complete filling of middle cerebral branches in (a) arrow indicates the point subsequently shown to be occluded In (b) persistence of candelabra shaped branches of this vessel in the venous phase indicates stasis resulting from the occlusion which apparently occurred at injection (c) and (d) Early and late arterial phases from a second lateral series a few minutes later Following this the patient s clinical signs of a neurologic complication were first noted In (c) only insular portion of occluded vessel can be identified The peripheral branches are not filled producing an avascular region in the frontoparietal area In (d) the occluded vessel is filled to point indicated by open arrow Subsequent films showed no progression of contrast material beyond this point suggesting that this was the site of the occlusion The solid arrow points to a peripheral branch of the occluded vessel which filled in retrograde fashion from anastomoses with the anterior cerebral artery This same branch can be seen in frames (a) and (b) filling in normal prograde fashion This illustrates the immediate availability of leptomeningeal collateral anastomoses in the case of an occlusion

Case 2 A 65 year-old right handed male with a previous diagnosis of a hypernephroma was examined because of a focal right sided seizure *one week prior* to admission Physical examination showed a slight right upper monoparesis with decreased proprioceptive and vibratory sensation in the right hand A percutaneous left carotid arteriography was done Because of what was thought to be a technical error 2 lateral series were exposed *in rapid succession* Immediately *afterwards* the patient was noted to be aphasic with a right central facial paresis and a complete right upper monoplegia The films showed that an occlusion of a frontoparietal branch of the middle cerebral artery in the region of the motor cortex had occurred at the time of the first injection (*Fig* 2) *This was presumed to be embolic* Within 3 days after the angiography the patient had regained considerable strength in the extremity The aphasia and a minimal paresis in the right arm were however still present 14 days later

The first series of lateral films demonstrated the occlusion of the vessel after some contrast material had entered it (*Fig* 2 *a and b*) *This produced sudden stasis in the vessel* and the branches remained filled with contrast medium for a prolonged period of time The second lateral series of films then showed the vessel to be totally occluded (Fig 2 c and d) The peripheral branches which had filled in normal fashion minutes before were now seen to fill in a retrograde direction via collateral vessels from the anterior cerebral artery

Comments The carotid angiographies in Cases 1 and 2 were performed by percutaneous puncture of the common carotid artery with a disposable 18 gauge $3^1/_2$ inch spinal needle *Following puncture of the vessel and between injections* the stylet was replaced *in the* cannula While this technic was in use a total of 8 cases in a series of 150 consecutive cerebral angiographies were seen in which small peripheral branch occlusions were identified following the procedure Of these occlusions 5 were asymptomatic Most of them were found in patients who were examined for conditions other than ischemic cerebrovascular disease and two were in patients in their second decade

No source of emboli was apparent in the neck vessels nor was there evidence of a subintimal *injection at the site of the needle Speculation as to the source of the emboli therefore* led us to examine the needle used The needle has a dead space in the hub around the stylet in which clots may form Fragments of clot may be extruded from the cannula by insertion of the stylet or by the forceful injection of contrast material The incidence of this complication decreased markedly when instead of replacing the stylet a transparent connecting tube was attached to the cannula following puncture of the vessel The tubing and the needle were flushed frequently with sterile saline

Both cases demonstrated the immediate availability of *collateral channels in the* leptomeninges between the anterior cerebral and middle cerebral arteries Within minutes of the occlusion the collateral vessels were of sufficient calibre to fill the peripheral branches of the occluded vessel with contrast material

Case 3 A 60 year old right handed female was investigated because of a 6 months history of *episodic vertigo and ataxia precipitated by* lateral rotation of the head Except for a blood pressure of 160/110 and the residual of an old left facial palsy her *examination was normal* Aortography was done to demonstrate the extracranial cerebral vessels A preshaped yellow *Ödman catheter* with several side holes was introduced into the right femoral artery without difficulty and passed into the ascending aorta. Three *injections of Renografin 76* (Methyl glucamine diatrizoate) were made for a p and oblique projections using a pressure injector The tip of the catheter was then placed selectively in the right carotid artery and 2 injections of Renografin 60 were made by hand for lateral and a p views of the intracranial vessels After further manipulation during which it was necessary to insert the guide wire the cathe

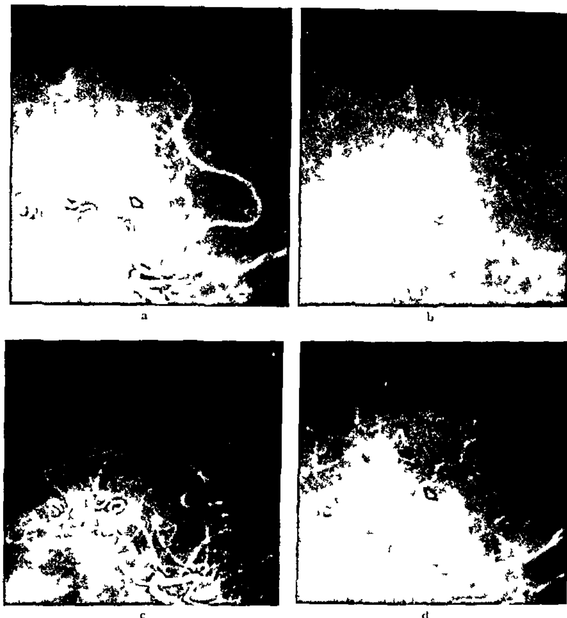


Fig 2 Case 2 a) and b) Early arterial and early venous phases from first lateral series Complete filling of middle cerebral branches in (a) arrow indicates the point subsequently shown to be occluded In (b) persistence of candelabra shaped branches of this vessel in the venous phase indicates stasis resulting from the occlusion which apparently occurred at injection c) and d) Early and late arterial phases from a second lateral series a few minutes later Following this the patient s clinical signs of a neurologic complication were first noted In (c) only insular portion of occluded vessel can be identified The peripheral branches are not filled producing an avascular region in the frontoparietal area In (d) the occluded vessel is filled to point indicated by open arrow Subsequent films showed no progression of contrast material beyond this point suggesting that this was the site of the occlusion The solid arrow points to a peripheral branch of the occluded vessel which filled in retrograde fashion from anastomoses with the anterior cerebral artery This same branch can be seen in frames (a) and (b) filling in normal prograde fashion This illustrates the immediate availability of leptomeningeal collateral anastomoses in the case of an occlusion

proved slightly and she began to respond to verbal commands At the time of discharge 13 days after the angiography the motor aphasia was present without evidence of the right hemiparesis

Comments In Case 3 the films revealed occlusions in branches of the middle and anterior cerebral arteries in a patient who developed signs of focal left hemisphere dysfunction following an injection into the left common carotid artery The indispensability of serial films was demonstrated by this case In the early lateral films branches of the middle cerebral artery on the opposite side which had filled via the anterior communicating artery appeared to fill the area shown on later films to be avascular The occlusions in the anterior cerebral artery were obscured by the opposite anterior cerebral artery and it was not until the delayed films that the occlusion became apparent

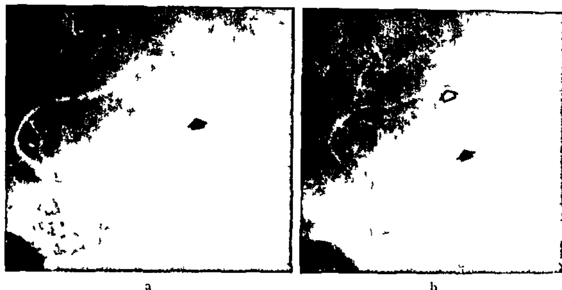
The finding of multiple small occlusions suggested that the injection had produced multiple emboli The emboli were probably related to the use of a thick walled catheter with side holes In order to manipulate the catheter into the left common carotid artery a spring guide wire had been inserted into the catheter During the several minutes required for this maneuver the catheter could not be adequately flushed Inspection of the catheter following its withdrawal suggested that clots had formed in the side holes Because of slight narrowing of the diameter of the side holes toward the lumen of the catheter subsequent aspiration was unlikely to dislodge them but they could be ejected by the force of a vigorous hand injection

Discussion

During cerebral angiography by either direct percutaneous puncture or indirect catheterization of the carotid arteries embolic occlusions of small intracerebral arteries have been identified In some cases a neurologic complication appropriate to the site of the occlusion resulted from the procedure in other cases the patients were asymptomatic Analysis of the cases suggested that the emboli were related to the angiographic technic This presumption was supported by a decrease in the incidence of such complications when the technic was changed

Embolic complications may have been unrecognized previously due to the difficulty in identifying small intracerebral occlusions The validity of the criteria for occlusion have been confirmed by biopsy or autopsy finding of cerebral infarction in three cases not described in this report Experimentally produced emboli in humans present a similar angiographic appearance (12) The demonstration of such occlusions may only be possible radiologically Small arterial occlusions are difficult to identify at post mortem examination even when accompanied by infarction Spontaneous lysis which may occur within hours to days of an occlusion may partially explain this difficulty (20)

In most of the cases in which embolic occlusions were identified, the films obtained during the actual study enabled the diagnosis to be established In some cases in which a neurologic complication developing during angiography could not be explained by interference with blood flow in the carotid artery a repeat study was done immediately to determine the cause of the



a b

Fig 3 Case 3 a) and b) Mid arterial and early venous phases from a lateral series following percutaneous puncture of left carotid artery In (a) the right anterior cerebral artery is filled and obscures the left pericallosal artery In (b) the prolonged filling of the left pericallosal artery after the right anterior cerebral vessel had emptied indicates stasis and reveals the occlusion to be responsible A filling defect is present at the origin of the callosal marginal branch and is indicated by the left open arrow An abrupt termination of the pericallosal branch indicated by the right open arrow is another point of occlusion This appearance persisted during multiple films In (a) no branches of the middle cerebral artery are seen in the mid and posterior frontal regions The solid arrow points to beginning filling in retrograde fashion of one of the peripheral branches of the occluded middle cerebral vessel This branch is also indicated by a solid arrow in (b) where it is filled further toward the Sylvian fissure

ter was introduced into the left carotid artery to a point approximately 2 cm below the bifurcation A single injection of 8 ml of Renografin 60 % was made by hand for a lateral film of the neck Immediately after the injection it was noted that the patient was unresponsive to verbal stimuli and was aphasic The catheter was immediately pulled back from the left carotid artery into the aortic arch Her stretch reflexes were equal and no Babinski signs were elicited There was withdrawal to pain in all four extremities The blood pressure was unchanged The patient was given 5 % CO_2 in oxygen by face mask and her condition appeared to be stabilized An attempt was made to reinsert the catheter into the left carotid artery but it was unsuccessful During the manipulation of the catheter within the aortic arch it was noted that the patient had a right hemiparesis with a right Babinski sign and was less responsive to auditory stimuli than before Review of the films of the neck vessels and the right intracerebral vessels revealed no significant abnormalities

It was decided to continue the investigation by a different route in order to determine the cause of the stroke A percutaneous left carotid puncture was made and lateral serial films of the skull were exposed The films revealed occlusions in peripheral branches of both the anterior and middle cerebral arteries (Fig 3) This procedure did not change the patient s neurologic status but her blood pressure decreased from 150/90 to 180/60 Within 24 hours there was considerable improvement in the right hemiparesis but the aphasia which was both receptive and motor persisted Over the next 12 days the patient s mental status im

proved slightly and she began to respond to verbal commands At the time of discharge 13 days after the angiography the motor aphasia was present without evidence of the right hemiparesis

Comments In Case 3 the films revealed occlusions in branches of the middle and anterior cerebral arteries in a patient who developed signs of focal left hemisphere dysfunction following an injection into the left common carotid artery The indispensability of serial films was demonstrated by this case In the early lateral films branches of the middle cerebral artery on the opposite side which had filled via the anterior communicating artery appeared to fill the area shown on later films to be avascular The occlusions in the anterior cerebral artery were obscured by the opposite anterior cerebral artery and it was not until the delayed films that the occlusion became apparent

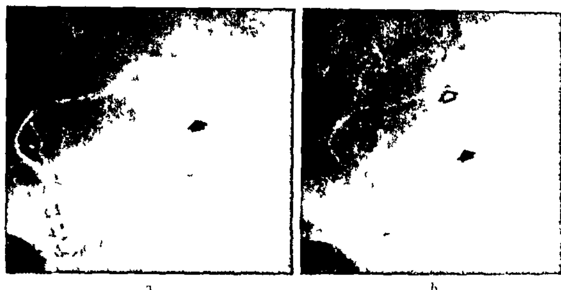
The finding of multiple small occlusions suggested that the injection had produced multiple emboli The emboli were probably related to the use of a thick walled catheter with side holes In order to manipulate the catheter into the left common carotid artery a spring guide wire had been inserted into the catheter During the several minutes required for this maneuver the catheter could not be adequately flushed Inspection of the catheter following its withdrawal suggested that clots had formed in the side holes Because of slight narrowing of the diameter of the side holes toward the lumen of the catheter subsequent aspiration was unlikely to dislodge them but they could be ejected by the force of a vigorous hand injection

Discussion

During cerebral angiography by either direct percutaneous puncture or indirect catheterization of the carotid arteries, embolic occlusions of small intracerebral arteries have been identified In some cases a neurologic complication appropriate to the site of the occlusion resulted from the procedure in other cases the patients were asymptomatic Analysis of the cases suggested that the emboli were related to the angiographic technic This presumption was supported by a decrease in the incidence of such complications when the technic was changed

Embolic complications may have been unrecognized previously due to the difficulty in identifying small intracerebral occlusions The validity of the criteria for occlusion have been confirmed by biopsy or autopsy finding of cerebral infarction in three cases not described in this report Experimentally produced emboli in humans present a similar angiographic appearance (12) The demonstration of such occlusions may only be possible radiologically Small arterial occlusions are difficult to identify at post mortem examination even when accompanied by infarction Spontaneous lysis, which may occur within hours to days of an occlusion may partially explain this difficulty (20)

In most of the cases in which embolic occlusions were identified the films obtained during the actual study enabled the diagnosis to be established In some cases in which a neurologic complication developing during angiography could not be explained by interference with blood flow in the carotid artery, a repeat study was done immediately to determine the cause of the



a b

Fig. 3. Case 3. a) and b) Mid arterial and early venous phases from a lateral series following percutaneous puncture of left carotid artery. In (a) the right anterior cerebral artery is filled and obscures the left pericallosal artery. In (b) the prolonged filling of the left pericallosal artery after the right anterior cerebral vessel had emptied indicates stasis and reveals the occlusion to be responsible. A filling defect is present at the origin of the callosal marginal branch and is indicated by the left open arrow. An abrupt termination of the pericallosal branch indicated by the right open arrow is another point of occlusion. This appearance persisted during multiple films. In (a) no branches of the middle cerebral artery are seen in the mid and posterior frontal regions. The solid arrow points to beginning filling in retrograde fashion of one of the peripheral branches of the occluded middle cerebral vessel. This branch is also indicated by a solid arrow in (b) where it is filled further toward the Sylvian fissure.

ter was introduced into the left carotid artery to a point approximately 2 cm below the bifurcation. A single injection of 8 ml of Renografin 60% was made by hand for a lateral film of the neck. Immediately after the injection it was noted that the patient was unresponsive to verbal stimuli and was aphasic. The catheter was immediately pulled back from the left carotid artery into the aortic arch. Her stretch reflexes were equal and no Babinski signs were elicited. There was withdrawal to pain in all four extremities. The blood pressure was unchanged. The patient was given 5% CO_2 in oxygen by face mask and her condition appeared to be stabilized. An attempt was made to reinsert the catheter into the left carotid artery but it was unsuccessful. During the manipulation of the catheter within the aortic arch, it was noted that the patient had a right hemiparesis with a right Babinski sign and was less responsive to auditory stimuli than before. Review of the films of the neck vessels and the right intracerebral vessels revealed no significant abnormalities.

It was decided to continue the investigation by a different route in order to determine the cause of the stroke. A percutaneous left carotid puncture was made and lateral serial films of the skull were exposed. The films revealed occlusions in peripheral branches of both the anterior and middle cerebral arteries (Fig. 3). This procedure did not change the patient's neurologic status but her blood pressure decreased from 150/90 to 180/60. Within 24 hours there was considerable improvement in the right hemiparesis but the aphasia which was both receptive and motor persisted. Over the next 12 days the patient's mental status im

The decrease in the incidence of embolic complications during direct needle angiography when the replacement of the stylet was eliminated led us to believe that the emboli were most likely fragments of blood clot, it was not until after the incidence of emboli had decreased that a change was made to a closed system for flushing the needle It is also likely that blood clots were the emboli in Case 3 since the occlusions produced by cotton fibers in the documented cases have been in vessels much smaller than those involved in this case

It is obvious that the elucidation of the cause of angiographic complications is essential to the elimination of such complications The detection of asymptomatic emboli may lead to changes in technic which will prevent more serious complications in other cases For these reasons as well as others it is important to study the angiographic films for small vessel occlusions Careful comparison between the films of different series and between the current study and any previous study may make small occlusions obvious

Acknowledgement

We are grateful to Dr Herbert L Abrams Professor of Radiology and Director of the Diagnostic Division for his critical review of this manuscript

SUMMARY

Three cases are reported in which significant complications of cerebral angiography were due to emboli The emboli were thought to arise in the hub of the needle used in two cases and in the side holes of a catheter in the third The technical means to avoid such complications are discussed The detection of small intracerebral occlusions indicates the need to examine the technic used in order to eliminate the possibility of iatrogenic emboli The cases reported also document the immediate availability of leptomeningeal anastomoses as a source of collateral supply to an occluded vessel

ZUSAMMENFASSUNG

Drei Falle mit signifikanten Komplikationen bei zerebraler Angiographie waren durch Embolie verursacht Der Ursprung der Embolie wurde in zwei Fallen in der Injektionsnadel und in einem Fall in der seitlichen Öffnung eines Katheters vermutet *Es werden die technischen* Mittel zur Verhinderung solcher Komplikationen besprochen Die Entdeckung von kleinen intracerebralen Verschlussen weist auf die Notwendigkeit hin die angewendete Technik zu uberprufen um das Risiko von iatrogenen Embolien *zu beseitigen* Die berichteten Falle beweisen auch das Vorhandensein von leptomeningealen Anastomosen wovon die Kollateralzirkulation zu einem verschlossenen Gefass ausgeht

RÉSUMÉ

Présentation de trois cas ou des complications graves de l angiographie cérébrale étaient dues a des embolies Les auteurs pensent que les emboles se sont

complication This did not appear to increase the severity of the neurologic complication

While blood clots originating from the needle are mentioned as a possible source of emboli in discussions of complications, this has not often been documented (5, 16) Emboli to the retina as a complication of angiography have in general been thought to be associated with atherosclerosis (1, 8, 13, 15) LEVINE & HENRY (11), however, have reported retinal embolization following carotid angiography without evidence of underlying arteriosclerotic disease

It is not possible to establish how often embolic complications occur during catheter angiography LANG reported 9 cases of arterial embolization in a review of 11 402 percutaneous angiograms (9) EDLING & OVENFORS have found small infarcts in dogs after selective renal arterial catheterization which they attributed to blood clots (6, 7) It is likely that most small emboli are asymptomatic in viscera other than the brain and are consequently undetected

BOIJSEN & FEINSTEIN discussed the potential hazards of catheters with side holes, such as the formation of emboli from clots (2) They suggested that this type of catheter should be avoided for selective examinations except in angiocardiography OLIN has reported that clots are more likely to form in side holes in thick walled radio opaque catheters than in thin walled non opaque polyethylene catheters and he has emphasized the necessity for vigorous flushing of these catheters while they are in place (14) At the present time we limit the use of such catheters to placements within large vessels that do not require prolonged manipulation and we exclude their use from any selective studies of the cerebral vessels With the increased use of catheter techniques for the study of cerebral vessels, particularly in the older age groups, careful attention to technical problems will be necessary to avoid embolic complications

It is possible that the emboli may have been foreign material such as cotton fiber particles Such particles may arise either from wiping the needle, stylet, or wire leader with gauze containing short cotton fibers or from using solutions contaminated with cotton particles to flush the needle or catheter (1, 3, 17) Our pathologist has found evidence of such emboli in specimens obtained after selective renal catheterization and direct needle carotid angiography Experimental work in animals in our laboratories has confirmed the large number of potential embolic particles that can accumulate in open bowls (1) It is now routine in all of our vascular studies to use a closed system for flushing solutions This is conveniently done by using a standard commercial intravenous solution and tubing set which is connected to a stopcock on the catheterization tray The solution is drawn into the syringe used for flushing by connecting it to the stopcock

The decrease in the incidence of embolic complications during direct needle angiography when the replacement of the stylet was eliminated led us to believe that the emboli were most likely fragments of blood clot, it was not until after the incidence of emboli had decreased that a change was made to a closed system for flushing the needle It is also likely that blood clots were the emboli in Case 3 since the occlusions produced by cotton fibers in the documented cases have been in vessels much smaller than those involved in this case

It is obvious that the elucidation of the cause of angiographic complications is essential to the elimination of such complications The detection of asymptomatic emboli may lead to changes in technic which will prevent more serious complications in other cases For these reasons as well as others it is important to study the angiographic films for small vessel occlusions Careful comparison between the films of different series and between the current study and any previous study may make small occlusions obvious

Acknowledgement

We are grateful to Dr Herbert L Abrams Professor of Radiology and Director of the Diagnostic Division for his critical review of this manuscript

SUMMARY

Three cases are reported in which significant complications of cerebral angiography were due to emboli The emboli were thought to arise in the hub of the needle used in two cases and in the side holes of a catheter in the third The technical means to avoid such complications are discussed The detection of small intracerebral occlusions indicates the need to examine the technic used in order to eliminate the possibility of iatrogenic emboli The cases reported also document the immediate availability of leptomeningeal anastomoses as a source of collateral supply to an occluded vessel

ZUSAMMENFASSUNG

Drei Falle mit signifikanten Komplikationen bei zerebraler Angiographie waren durch Embolie verursacht Der Ursprung der Embolie wurde in zwei Fallen in der Injektionsnadel und in einem Fall in der seitlichen Öffnung eines Katheters vermutet Es werden die technischen Mittel zur Verhinderung solcher Komplikationen besprochen Die Entdeckung von kleinen intracerebralen Verschlussen weist auf die Notwendigkeit hin die angewendete Technik zu überprufen um das Risiko von iatrogenen Embolien zu beseitigen Die berichteten Falle beweisen auch das Vorhandensein von leptomeningealen Anastomosen wovon die Kollateralzirkulation zu einem verschlossenen Gefass ausgeht

RÉSUMÉ

Présentation de trois cas ou des complications graves de l angiographie cérebrale étaient dues a des emboles Les auteurs pensent que les

l aiguille utilisée dans deux cas et dans les trous latéraux du cathéter dans le troisième cas Ils examinent les moyens d éviter ces complications La découverte de petites obstructions artérielles intracérébrales rend nécessaire l examen de la technique utilisée pour éliminer la possibilité d embolies iatrogéniques Les cas présentés montrent aussi le fonctionnement immédiat d anastomoses leptoméningées pour l irrigation collatérale d un vaisseau obstrué

REFERENCES

1 ADAMS D OLIN I and KOSEK J Cotton fiber embolization during angiography Radiology 84 (1965), 678
2 BOIJSEN E and FEINSTEIN G L Arteriographic catheterization technic Am J Roentgenol 85 (1961) 1037
3 CHASON J L, LANDERS J W and SWANSON R E Cotton fiber embolism A frequent complication of cerebral angiography Neurology 13 (1963) 558
4 DAVID N J, KLINTWORTH G K FRIEDBERG S J and DILLON M Fatal atheromatous cerebral embolism associated with the appearance of bright plaques in the retinal arterioles Neurology 13 (1963) 708
5 EIKEN M and GORMSEN J Complications of carotid angiography in acute cerebrovascular conditions Acta Med scand 172 (1962) 151
6 EDLING N P G and OVENFORS C O Risks in selective renal catherization and arteriography Acta radiol 2 (1964) 241
7 — — Intentional embolism in selective renal arteriography Acta radiol 2 (1964) 316
8 HANEY W P and PRESTON R F Ocular complications of carotid arteriography in carotid occlusive disease Arch Ophthal 67 (1962) 127
9 LANG E K A survey of the complications of percutaneous retrograde arteriography Radiology 81 (1963) 257
10 LANNER L O and ROSENGREN K Angiographic diagnosis of intracerebral vascular occlusions Acta radiol 2 (1964) 129
11 LEVINE R A and HENRY M D Ischemic infarction of the retina following carotid angiography Am J Opthal 55 (1963) 365
12 LUESSENHOP A J GIBBS M and VELASQUEZ A C Cerebrovascular response to emboli Arch Neurol 7 (1962) 264
13 MCBRIEN D J BRADLEY R D and ASHTON N Nature of retinal emboli in stenosis of the internal carotid artery Lancet 1 (1963) 697
14 OLIN T Studies in angiographic technique p 96 Håkan Ohlssons Boktryckeri Lund 1963
15 ROSS R R W Atheromatous retinal embolism Lancet 2 (1963) 1354
16 SCHEINBERG P and ZUNKER E Complications in direct percutaneous carotid arteriography Arch Neurol 8 (1963) 676
17 SILBERMAN J CRAVIOTO H and FEIGIN I Foreign body emboli following cerebral angiography Arch Neurol 3 (1960) 711
18 TAVERAS J M Angiographic observations in occlusive cerebrovascular disease Neurology 11 (1961) 86
19 WICKBOM I Survey of the angiographic technique used in patients suspected of cerebral ischemia Ann Radiol 6 (1963) 23
20 ZATZ L M IANNONE A M ECKMAN P B and HECKER S P Observations concerning intracerebral vascular occlusions Neurology 15 (1965) 389